Feed Utilization by Cattle

Availability of Phosphorus in dairy feeds
M.J. Aguerre, S. Marcot, H. Henselmeyer, and L.D. Satter

Introduction

Dairy diets in the U.S. typically contain more phosphorus (P) than is required, resulting in added cost (~$100 million annually in the U.S.) and increased risk of environmental damage. One reason dairy diets are formulated to contain excess P is due to uncertainty regarding the P requirement. One aspect of the uncertain requirement relates to availability of dietary P in the gastrointestinal tract. This study was conducted to determine availability of P in soybean meal and cottonseed.

Methods and Procedures

Three trials were conducted. In trial 1 and 2, 10 and 9 cows in mid to late lactation were fed for 3 wks a low P basal diet (BD) containing 0.17-0.19%P (dry basis). During the last 3-d of the third wk 12 fecal samples (dispersed through the 24-hour day) were collected. Ytterbium was used as an external marker for estimating DM digestibility. Following this three wk period, all cows were assigned to a trt diet where the test feed (soybean meal and corn gluten feed for trials 1 and 2) was inserted to provide a source of P. The test feed replaced P-free starch in the BD and increased P content of the test diets to approximately 0.3%. Fecal samples were obtained during the last 3 days of the two-wk test period. This cycle was repeated in trial 1 and 2, this time with cottonseed and corn distillers grain. Dry matter digestibility estimates from the two BD periods were averaged for calculating P availability of the two test feeds for trial 1. Marker problems prevented DM digestibility estimates in trial 2, so values of 67 and 65% were assumed for BD diets. The incremental increase in fecal P excretion due to feeding of the test feed was considered as unavailable P. Trial 3, utilizing 10 cows, was conducted in the same way, except there was only one BD period sandwiched between two test feed periods (porcine meat and bone meal and dicalcium P).

Results and Discussion

The basal diet was clearly deficient in phosphorus. When the test feed was included in the diet, dietary phosphorus would have been very close to meeting the requirement. As shown in the table, availability of phosphorus ranged between 64% for meat and bone meal to 85% for dicalcium phosphate. Meat and bone meal probably contained larger pieces of bone than typical bone meal preparations, so this availability value should not necessarily be extended to bone meal.

Conclusion

The NRC "Nutrient Requirements of Dairy Cattle" (2001) uses availability values of 64 and 70% for forages and concentrates, respectively. The availability of P, as measured in this experiment, ranged between 73 and 83% for concentrate. Availability of P in bone meal and dicalcium phosphate was 64 and 85%, respectively. These slightly higher availability values for concentrations suggest that there may be some margin of safety implied in calculating P requirements when using NRC (2001) recommendations for formulating dairy diets.

Phosphorus availability in soybean meal, cottonseed, gluten feed, corn distillers grain, and dicalcium phosphate

	DMI (kg/day)	DM Digestibility(%)	P intake (g/day)	P excreted (g/day)	P Availability (%)
Trial 1 (n=10)					
BD	19.2	64	33.0	19.8	
BD+soybean meal	20.7	63	51.3	26.0	74
BD	20.0	64	34.5	23.8	
BD+cottonseed	20.2	66	48.1	24.4	81
Trial 2 (n=9)					
BD	18.5	67	33.3	20.9	
BD+corn gluten feed	20.7	65	66.1	29.7	73
BD	17.0	67	30.6	19.0	
BD+corn distiller grain	17.0	65	49.2	22.4	83
Trial 3 (n=10)					
BD+meat and bone meal	21.2	70	61.4	31.0	64
BD	20.2	74	40.5	23.0	
BD+dicalcium phosphate	21.7	68	65.1	26.9	85

Measuring Volatile Nitrogen Losses from Dairy Farms in Wisconsin
V.R. Moreira and L.D. Satter

Introduction

Nitrogen losses from livestock excreta are due primarily to ammonia volatilization before manure is fully incorporated into the soil. Mass balances, i.e., calculating nutrient excretion as the difference between intake and product amounts is considered reasonably accurate. Measuring N disappearance from open-dirt feedlots in Nebraska, found losses up to 60 to 70% of excreted N. Volatile N losses were greater in summer than in winter. There have been reported differences in N losses from different practices in European dairy farms. In the US, an inventory of N losses is still lacking for most species, especially dairy operations.

In this survey we intended to measure N disappearance from manure of lactating dairy cows. The nitrogen to phosphorus ratio (N/P) in manure sampled from commercial dairy farms is being used to estimate volatile N losses.

Materials and Methods

Thirteen farms were initially selected for manure collection in the Spring of 2001. Due to numerous reasons, we were able to use the results of only five farms hereafter identified as 4, 5, 6, 9, and 10. Lactating cows at farm 4 were kept in a sand bedded free stall barn (Table 1). Manure was scraped twice daily, and top loaded into a concrete walled pit located under the free stall barn roof. This was emptied about every two to three weeks. Mixing occurred only before hauling the approximately 18 loads needed to empty the manure pit. This farm was surveyed twice for that season. On farm 5, lactating cows were held on a slatted floor, sawdust bedded free stall. Approximately 340,000 gallons of manure from the previous six months were pumped through a hose to the fields from the storage located beneath the slatted floor. This storage was well mixed throughout the entire emptying time.

Lactating cows on farm 6 were maintained in a sand bedded free stall barn. The barn was scraped 3x daily. Three to four loads were hauled daily from a top loaded, covered cement manure storage located under the barn floor. Manure was not mixed in this daily haul system. On farm 9, there were primarily lactating cows in a sand bedded free stall barn. The barn was scraped 3x/d and manure was hauled with minimum of mixing. On farm 10, cows were housed in a free stall with sand for bedding. Manure was scraped 3x/d, and loaded from the bottom of the storage, but was never completely emptied.

The ratio between N and P (N/P ratio) was chosen in this survey, using P as a marker that was assumed to have a recovery of 100%. Manure samples were collected throughout the emptying of manure storages. Sampling rates varied from every two loads for the smaller storages to twice daily in the larger one. Temperature and pH were measured at time of sampling. Samples of feeds as well as manure were analyzed for total nitrogen and total phosphorus.

Results and Discussion

Results presented in this report are preliminary. Dietary N and P levels were calculated from individual feed analyses and are presented in Table 1. Excreted N/P ratios were calculated based on the difference between daily nutrient intakes and amounts secreted in milk. Milk CP and phosphorus were assumed to be 3.15% and 0.09%, respectively.

The NRC (2001) model was used to estimate DM intake from body weight, milk production, DIM and CP values. Chemical composition of lactating cows' diets varied relatively little among farms.

Nutrient content of manure samples and calculated N disappearance are presented in Table 2. The ratio between manurial N and P (X=6.01; sd=0.52) only varied 8.74%, but resulted in 45.5% variation in the percentage of losses among the systems (X=15.92%; sd=7.24). As expected, lower losses occurred with the three times daily scraping, daily haul protocol (4.0%). Scraping three times a day and bottom loading was intermediate (16.9 and 16.2%), while scraping twice a day and top loading had the highest losses (19.0 and 23.5%) of the excreted N.

Conclusion

There are differences among dairy systems in N disappearance from manure. There is need for more quantitative data relating manure handling systems to volatile nitrogen losses.

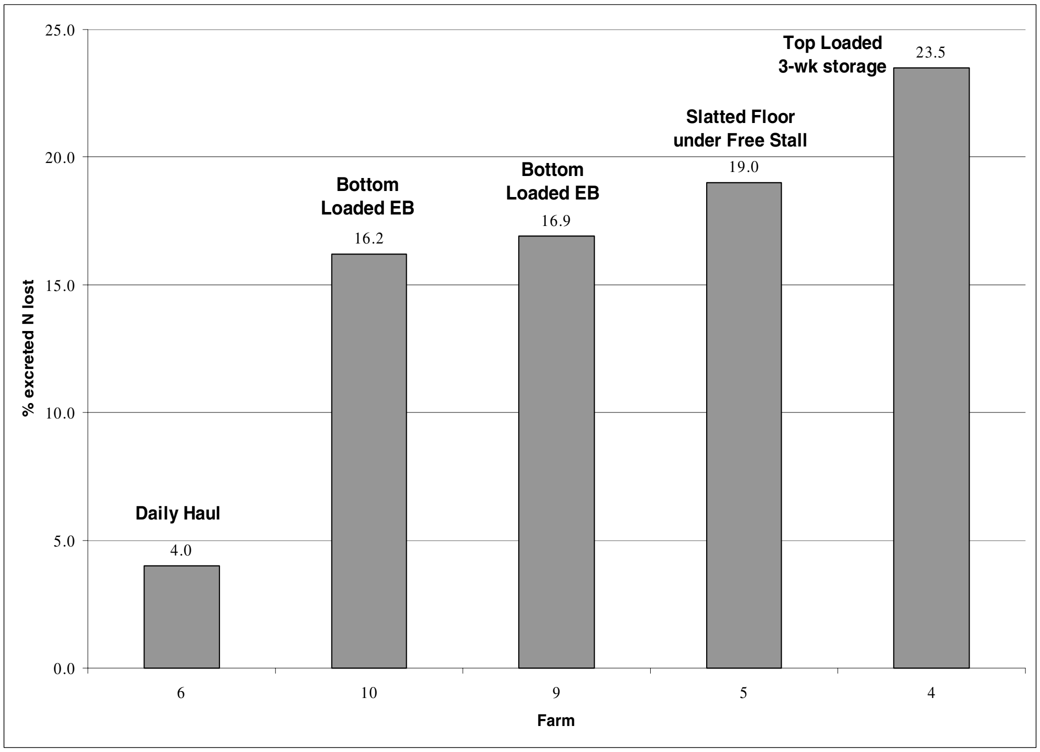
Table 1. Dietary composition, milk yield and composition, and nutrient excretion of five farms investigated in Wisconsin.

Farms	4	5	6	9Lact	9Dry	10
Average Dietary TN (%DM)	2.98	2.84	2.59	2.81	2.29	2.76
Average Dietary P (%DM)	0.45	0.44	0.41	0.38	0.36	0.41
DMI (kg/d)	24.9	24.9	28.2	23.6	5.4	25.8
Milk yield (kg)	34.1	35.8	42.2	29.9	0	36.3
Milk N (%)	0.49	0.49	0.49	0.49	0	0.49
Excreted N/P	7.05	6.80	6.72	7.82		7.40

Table 2. Manure characteristics and calculated losses.

Farms	4	5	6	9	10
pH	7.49	7.48	8.52	7.12	6.85
T (^{o}C)	13.60	10.45	10.50	20.94	18.41
DM (%)	14.85	7.85	9.07	17.75	15.87
TN (%DM)	2.88	4.34	3.65	2.65	2.51
Ash (%DM)	47.20	23.48	43.09	53.99	57.30
P (%DM)	0.52	0.81	0.59	0.40	0.39
Manure N/P	5.39	5.51	6.45	6.49	6.20
% N disappearance	23.5	19.0	4.0	16.9	16.2

[1] High due to sand bedding.



EB= Earthan Basin

Effect of Feeding Brown Midrib Corn Silage or Conventional Corn Silage Cut at Either 9” or 28” on Milk Yield and Milk Composition

D.D. Dominguez, V.R. Moreira and L.D. Satter

Introduction

Brown midrib (bm3) corn silage has been shown to increase milk production over control corn silage, due most likely to its lower lignin content and greater digestibility. Another approach to improving digestibility of corn silage is to cut corn silage at a greater height at harvest time, thus leaving behind the relatively indigestible lower stalk. The objective of this experiment was to measure milk production when bm3 corn silage or conventional corn silage cut at either 9” or 28” above ground level was fed to lactating dairy cows.

Materials and Methods

Thirty lactating Holstein cows averaging 113 days in milk and 37.3 kg milk daily were randomly assigned (n=5) to one of six treatment groups (table 1) for use in a 6x6 Latin Square design. The treatments were designed to give two levels of dietary NDF (28 and 33%), and three corn silage sources- bm3, low cut (9”), or high cut (28”). The bm3 was Cargill 657, and the control corn silage for both low and high cut was Dekalb 520 RR. The length of each of four experimental periods was three weeks, with the first week used for adaptation.

The corn silages were cut at a theoretical cut length of 3/8”, and were not processed. Milkline at harvest was about .65 for the control corn silage, and .83 for the bm3.

Cows were housed in a tie stall barn, and fed once daily. Feed refusals and samples of the TMR and individual forages were collected daily and composited weekly. Cows were milked twice daily. Milk samples were taken on one day during each of the last two weeks of each period (am and pm) and measured for milk components.

Statistical analysis was done using an unbalanced and incomplete 6x4 Latin square, using the general linear models procedure in SAS.

Results and Discussion

Dry matter, CP, NDF, and ADF content of LC and HC corn silages were (%): 38.4, 6.7, 38.6, and 23.9; 40.9, 7.0, 33.9, and 20.5. Cutting corn silage at 28” rather than 9” increased dry matter content and decreased NDF and ADF content.

Table 2 contains performance information. Dry matter intake was higher for the bm3 treatment. Milk production tended to be higher with the bm3 treatment. The high-cut corn silage treatments supported the same amount of milk production as the low-cut treatments, but did so with diets containing greater amounts of forage. Milk composition was not different.

Conclusion

The bm3 treatment tended to have more milk production, but feed intake was increased with this treatment, so feed efficiency was reduced. Cutting corn silage higher results in an increase in DM content of the harvested forage and a decrease in NDF and ADF content. Lactation diets formulated to an equal NDF content enable diets with greater forage content when corn silage is harvested at a greater height, and it appears that milk production and milk composition will not be changed with these higher forage diets.

Table 1. Ingredients and chemical composition of experimental diets (% DM)

	28% NDF			33 % NDF		
	LC[1]	HC[2]	Bm3[3]	LC[1]	HC[2]	Bm3[3]
Alfalfa Silage	19.9	20.9	20.4	25.3	26.5	24.8
High cut CS	0.00	42.60	0.00	0.00	54.0	0.00
Low cut CS	40.6	0.00	0.00	51.7	0.00	0.00
Bm3	0.00	0.00	41.6	0.00	0.00	50.7
High moisture shelled corn	20.0	17.5	18.1	4.07	2.20	5.37
Roasted soybeans	12.7	12.7	12.7	12.7	12.7	12.7
Soybean meal	5.07	4.57	5.50	4.50	2.87	4.70
Mineral and vitamin mix	1.73	1.73	1.73	1.73	1.73	1.73
Diet composition						
DM%	55.0	55.0	52.7	49.6	49.5	47.9
CP%	16.8	16.8	17.0	17.2	16.8	17.2
NDF%	28.8	27.6	29.2	33.5	32.0	33.0
ADF%	18.7	17.9	18.7	22.6	21.5	21.8

[1,2,3] Correspond to low cut, high cut and bm3 corn silages, respectively

Table 2. Performance and Milk Composition

	28% NDF			33% NDF			P value			
	NC	HC	Bm3	NC	HC	Bm3	NDF	Bm3 vs HC	Bm3 vs NC	HC vs NC
DMI (kg/d)	19.81[a]	20.28[a]	22.56[b]	19.71[a]	20.18[a]	23.21[b]	.6423	<.0001	<.0001	.2640
Milk Yield (kg/d)	34.11[a]	34.37[a]	35.04[a]	30.97[b]	31.50[b]	32.62[b]	<.0001	.2607	.0968	.6084
3.5% FMC	34.60[a]	34.81[a]	35.26[a]	32.40[b]	32.50[b]	33.75[a]	.0026	.3168	.2159	.8309
Fat (%)	3.61[a]	3.60[a]	3.57[a]	3.81[b]	3.69[b]	3.73[b]	.0433	.9659	.5469	.5182
Fat (kg)	1.22[a]	1.23[a]	1.24[a]	1.17[a]	1.15[b]	1.21[a]	.0695	.3656	.4135	.9134
Protein (%)	3.05[a]	3.07[a]	3.06[a]	3.01[a]	3.0[a]	3.0[a]	.044	.7873	.9731	.7566
Lactose (%)	4.69[a]	4.74[a]	4.73[a]	4.71[a]	4.75[a]	4.71[a]	.9589	.6011	.8193	.4453
Kg milk/kg feed DM	1.73[a]	1.74[a]	1.58[b]	1.58[b]	1.58[b]	1.45[c]	<.0001	<.0001	<.0001	.8395

Means in rows with different superscripts are different (P<.05)

Use of Brown Midrib 3 Corn Silage (Cargill's Fulltime Forage 657) as the Major Forage for Transition Cows.

H. Santos, V.R. Moreira, Z. Wu and L.D. Satter

Introduction

Brown midrib 3 (bm3) is a natural mutant that has been incorporated into a modern corn hybrid. This mutant has a defective step in the synthetic pathway of lignin, and presence of the mutant results in lower lignin content of plant tissue. Corn silage with the mutant gene is normally more digestible, and has been shown to increase milk production in a number of studies. The purpose of this study was to evaluate a bm3 corn silage hybrid (Cargill Fulltime Forage 657) as a major source of forage for cows in the last three weeks of the dry period and the first four weeks of lactation.

Materials and Methods

Cows (29 primiparous and 83 multiparous) were divided into three groups and balanced according to lactation number and 305d ME milk (multiparous). Two of the three groups were combined for one of two prepartum trts. Cows were placed in trt groups 3-4 wk (mean=23 days) before their projected calving date. The two prepartum diets contained 65% forage and 35% concentrate, with corn silage (CS) providing 60% and alfalfa silage (alf) 40% of the forage (DM basis). The control CS (Dekalb 512 RR) was stored in two tower silos, and the bm3 (Cargill F657) stored in a bag silo. After calving the three groups, two of which were fed control CS prepartum, were assigned to three postpartum diets for 4-5 wk (mean=33d). The control diet (control 55 F) contained 55% forage and 45% concentrate, with 58% of the F as control CS and the balance as alf. The second and third postpartum diets contained 65% F, 58% of which was CS and 42% alf. One of these was the control CS (control 65 F) and the other was bm3 CS (bm3 65F). Cows fed control CS prepartum were fed control CS postpartum. Cows were fed a TMR once daily in a tie stall barn.

Results

The dry matter (%) and crude protein, NDF and ADF (% of DM) of the control and bm3 corn silages averaged: 35.8, 39.6; 8.2, 7.7; 41.5, 37.2; 26.2, 23.0. Dry matter intake for primiparous and multiparous cows during the 3 week prepartum period were 9.6 and 13.5 kg/day for the control corn silage, and 10.1 and 13.8 kg/day for the bm3 silage. These differences were not significant.

Dry matter intake and yield of milk and milk components for the four wk post-partum period are shown in Table 1. Results are presented separately for primiparous and multiparous cows. No differences were noted between treatments in terms of DMI. Multiparous cows, with their higher milk production, responded positively to the bm3 65 F treatment, producing about 2 kg more milk per day than either of the other two treatments. This response was even larger in terms of 3.5% FCM because of the higher milk fat test with the bm3 65 F treatment. Milk protein content was not different between treatments for primiparous cows, but it was lower in multiparous cows for the bm3 65 F treatment.

The advantage of the bm3 treatment over the other two treatments increased progressively over the four week postpartum period, and averaged 1.28, 1.33, 2.32, and 2.67 kg per cow per day for weeks 1, 2, 3, and 4, respectively. This is illustrated further in Figure 1 which shows milk production for the three treatments during the 4 wk post-partum period as well as milk production for treatment groups after leaving their treatment diets and being placed on a common lactation diet. As pointed out previously, not all cows were available for continuing on with the post-experimental period, but the majority were. It is very interesting that the difference established between the bm3 treatment and the two control treatments during the first four weeks was sustained for at least an additional 9 wk. Milk production values for this post-experimental period were summarized only for the additional 9 wk because too few cows were available beyond this time.

Conclusion

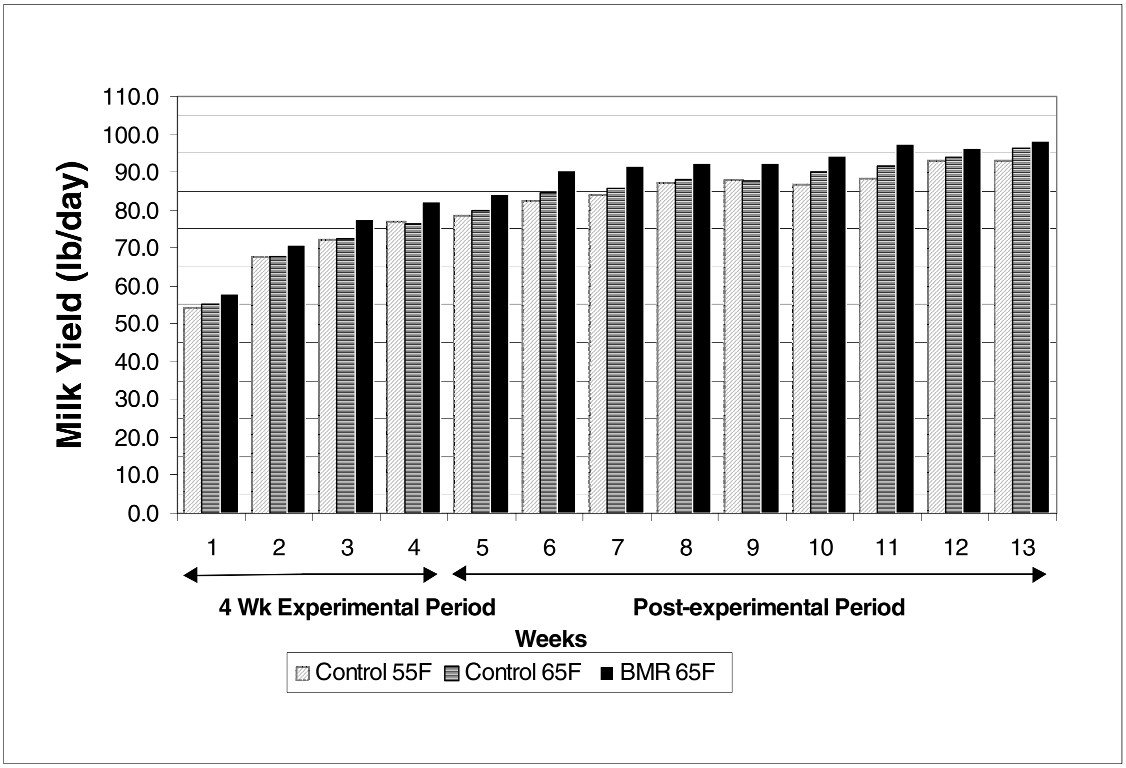
Feeding bm3 corn silage as a major part of the forage to cows in the last three weeks of the dry period and the first four weeks of lactation resulted in about two kg more milk during the first four weeks of lactation compared to cows fed a conventional corn silage hybrid. This difference tended to persist beyond the four week period during which bm3 was fed.

Table 1. Performance of cows during the first 4 wk postpartum.

	Treatment				*P*	
Item	Control 55 F	Control 65 F	bm3 65 F	SEM	Corn silage source[a]	Forage level[b]
DMI, kg/d						
Primiparous	13.0	13.1	12.8	1.1	0.84	0.91
Multiparous	16.7	16.9	17.1	0.6	0.78	0.85
Milk, kg/d						
Primiparous	25.0	24.5	24.3	1.6	0.93	0.82
Multiparous	33.4	32.9	35.2	1.0	0.09	0.75
3.5% FCM, kg/d						
Primiparous	27.9	28.1	29.2	2.1	0.73	0.94
Multiparous	38.9	39.4	42.2	1.2	0.10	0.75
Milk fat, %						
Primiparous	4.25	4.41	4.80	0.25	0.29	0.65
Multiparous	4.57	4.81	4.81	0.14	0.99	0.24
Milk protein, %						
Primiparous	3.29	3.24	3.28	0.11	0.84	0.74
Multiparous	3.35	3.47	3.26	0.06	0.02	0.20

[a]Control 65 F vs. bm3 65 F.
[b]Control 55 F vs. control 65 F.

MILK PRODUCTION BY WEEK POST-PARTUM



Milk Production, Phosphorus Excretion, and Bone Characteristics of Dairy Cows Fed Different Amounts of Phosphorus for Two or Three Years.
Z. Wu, A.J. Blohowiak, R.H. Stauffacher, J.H. Wilson, and L.D. Satter

Introduction

Although the data relating milk production to dietary phosphorus (P) content are substantial and convincing, more information is needed on the status of bone P as a function of dietary P. Bone serves as an important reservoir of P that can be mobilized to meet P requirements. A significant amount of bone P is made available in the first weeks of lactation when calcium is mobilized from bone to support lactation. The objective of this experiment was to obtain information on bone strength and bone P content after cows were fed low P diets for two or three lactations.

Materials and Methods

Thirty-seven multiparous Holstein cows were used in a 308 d lactation trial. Diets (Table 1) containing 0.31, 0.39, or 0.47% P (DM basis) were assigned to groups of 10, 14, and 13 cows at parturition. Molasses and beet pulp were included as diet ingredients because of their low P content, and this enabled formulation of a basal diet containing 0.31% P. Diets containing 0.39 and 0.47% P were obtained by adding monosodium phosphate to the low P diet. The 37 cows used in the present trial included 14 and 19 cows that were fed similar dietary P concentrations for one or two previous lactations, respectively. The remaining four cows (three in the 0.31% P group and one in the 0.39% P group) were new to this trial.

At the end of lactation, or in some cases, after cows were removed from the experiment but still milking and receiving the same diet, surgery was conducted to remove part of the 12th rib bone. Bone strength was tested, and bone ash and P content measured.

Results

Averages of dry matter intake over the lactation were similar among treatments (Table 1), indicating that varying P from 0.31 to 0.47% of the diet had no effect on ad libitum feed intake. Cows in all groups milked well, averaging > 11,900 kg/308 d. Milk production for the 0.31% P group was higher ($P < 0.10$) than that of the 0.39% P group, and appeared the highest of the three groups during the entire lactation. Interpretation of the milk production data from his trial needs caution. This trial was a continuation of trials carried out in the previous 1 or 2 yr, and cows remained on similar levels of dietary P without being randomly reallocated to treatments. We did this for the purpose of evaluating bone characteristics after long-term feeding of different amounts of P.

In Table 3 are each year's milk yield for just the cows that had been fed similar amounts of P for 2 or 3 yr. The yields for yr 1 and 2 were obtained from previous reports, and those for yr 3 from the current trial. Compared with 0.48 to 0.49% dietary P, feeding 0.31 or 0.38 to 0.40% P did not reduce the cow's milking capacity after 2 to 3 yr.

The concentration of inorganic P in blood serum was lower ($P < 0.01$) for cows fed the lowest P diet than for those fed the other diets; the overall means during the lactation were 5.7, 6.1, and 6.5 mg/dl (SE 0.1) for the 0.31, 0.39, and 0.47% P groups, respectively. The concentrations were similar toward the end of lactation. Serum P concentration can reflect P intake in ruminants, but it is not always a good indicator of P status. Only extremely low serum concentrations (<4 mg/dl) may indicate deficiency of P.

In a previous paper, we showed that the concentration of total P in milk appears to be related to milk protein concentration. A trend for this relationship again was observed in the present study using cows from all treatments ($r^2 = 0.21$, Figure 1). The average concentration of P in milk from this data set that involved 705 measures was 0.094% (SD 0.009). Extrapolation of the regression in Figure 1 to 0% protein indicates that P content of protein-free milk is 0.0487%, about half of the P present in milk containing 3.00 to 3.25% crude protein. This agrees with other observations that about half of the total P in milk is complexed with casein and the other half exists as diffusible ions or in milk serum (Farrell, 1988; Jenness, 1985). A cow having milk testing 4% rather than 3% crude protein would have about 0.0146 percentage units more P in the milk, or approximately 16% more total P (Figure 1). Since approximately 60% of the P requirement for a cow milking 40 kg/d is partitioned to milk production, and assuming the P maintenance requirement for the cow is independent of milk protein content, then a cow producing 4% protein milk (crude protein) should require about 10% more dietary P than a cow producing 3% protein milk. Our feeding standards need to reflect this.

No differences were found among treatments in the sheer stress the bone endured before rupture or the amount of energy required to deform the bone to the point of fracture (fracture energy) (Table 4). Wall thickness of the bone was 5.1 mm for all treatments. Bone specific gravity tended (P<0.1) to be lower for the 0.31% P treatment than for the other two treatments, with the difference being about 4%. The ash content of the bone, expressed on dry weight, wet weight, or wet bone volume, was slightly lower (P<0.06 to 0.13) for the 0.31% P group. The P content of bone was similar among treatments when expressed on an ash or dry weight basis, averaging 17.6 (SE 0.3) and 9.5% (SE 0.2), respectively. When expressed on a wet weight or volume basis, however, P content was lower (P<0.06 to 0.13) for the 0.31% P treatment compared to the 0.47% P treatment. The average decrease in ash and P content, based on measurements in dry weight, wet weight, and wet bone volume, was 4.8 and 6.0%, respectively, between the 0.31% and 0.47% P treatments.

Summary

Figure 2 is a summary of what we consider the status of P nutrition of lactating dairy cows producing >9000 kg/305 d lactation. The bare minimum of dietary P consistent with normal or near normal animal performance is 0.30%. At this amount, signs of P deficiency may be just appearing. At the other extreme of the continuum in Figure 2 is what most dairy producers in the United States are actually feeding. Several surveys show that dairy producers are feeding 0.46% to 0.50% dietary P. We consider the NRC recommendation as being more than adequate, but a reasonable level for the dairy industry to quickly move to. Feeding 0.35% P will provide a margin of safety above what might be considered a borderline deficient diet containing 0.30% and may be the choice for dairy producers facing serious nutrient management problems. If dairy producers reduce dietary P from current amounts to NRC recommended amounts, P excretion in manure will be reduced 25 to 30%, and P supplementation costs reduced by \$10 to \$15 per cow per lactation.

Table 1. Performance of cows fed diets differing in P content.

	Dietary P content(%)			
Item	0.31	0.39	0.47	SEM[a]
Number of cows	10	14	13	...
DMI, kg/d	25.0	25.0	24.6	0.6
Milk, kg/308-d	13,038	11,909	12,126	407[b]
3.5% FCM, kg/d	43.4	39.4	40.3	1.4[b]
Milk fat, %	3.64	3.50	3.64	0.12
Milk protein, %	3.16	3.13	3.10	0.05
Body weight during lactation				
Initial[1], kg	663	623	609	20[c]
Ending[1], kg	735	718	701	22
Change, g/d	277	345	320	76

[a]No treatment by month interaction for lactational measurements (P > 0.10).
[b]0.31% P > 0.39% P (P < 0.10).
[c]0.31% P > 0.47% P (P < 0.10).
[1]Initial weight was taken on an average DIM of 15 (SD 9), and ending weight at 290 DIM (SD 10).

Table 2. Strength measurements of the 12th rib bone from cows fed diets differing in P content for 2 to 3 yr.

	Dietary P content (%)			
Item	0.31	0.39-0.40	0.47-0.49	SEM
Number of cows[1]	9	9	11	...
Shear stress, N/mm^2 [2]	26.5	28.1	27.5	2.2
Fracture energy[2], N-m	66.6	60.5	65.0	4.2
Wall thickness, mm	5.1	5.1	5.2	0.1
Bone specific gravity[g]	1.50	1.57	1.55	0.02
Ash, % of dry weight	53.9[c]	56.2[a]	55.6[ab]	0.8
Ash, % of wet weight	46.0[c]	47.4	48.1[a]	0.7
Ash, g/cc, wet bone	0.69[c]	0.74[a]	0.74[a]	0.01
P, % of ash	17.7	17.3	17.9	0.3
P, % of dry weight	9.5	9.7	9.9	0.2
P, % of wet weight	8.1[c]	8.2	8.6[b]	0.2
P, g/cc, wet bone	0.122[c]	0.129	0.133[a]	0.003

[a, b, c]c < a (P <0.06), c < b (P < 0.13).
[g]Linear and quadratic (P < 0.14) effects.
[1]The nine cows sampled from the 0.31% P group included three cows that were fed this amount of P for 1 yr; all other cows sampled in this trial had been fed similar amounts of P for 2 or 3 yr.
[2]Area under the force (N) and deformation (m) curve. It is an expression of the amount of energy the bone absorbs before fracture.

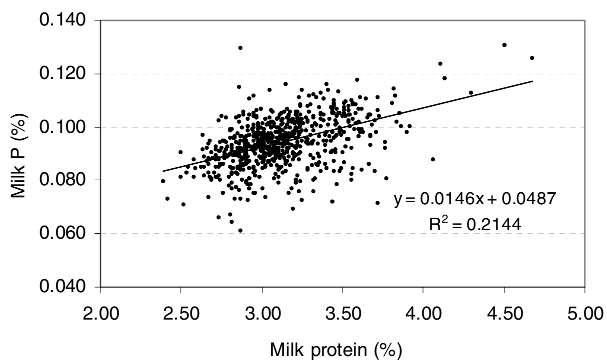


Fig. 1. Relationship between milk P concentration and milk crude protein content.

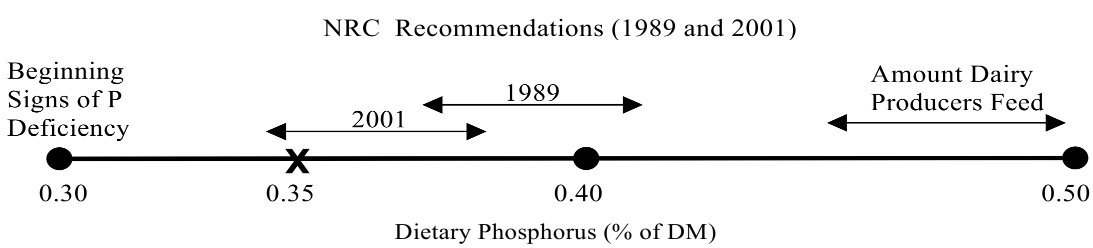


Fig. 2. Status of phosphorus nutrition of lactating dairy cows milking more than 9000 kg/305 d of lactation.

Effects of Replacing Dietary High Moisture Corn With Dried Molasses on Production of Dairy Cows

G.A. Broderick and W.J. Radloff

Introduction

An earlier feeding study (Broderick, Luchini et al., USDFRC Res. Summaries, 2001) indicated that replacing dietary corn starch with sugar (sucrose) increased DM intake and fat yield in cows fed an diet in which two-thirds of the forage was alfalfa silage. Although there were trends in ruminal concentrations of protein degradation products suggesting increased microbial protein formation, there were no significant changes in milk or protein yield in that study. Dried molasses is a practical source of dietary sugars for dairy cows. Therefore, we repeated our earlier trial, except that dried molasses was added to an alfalfa silage-based diet at the expense of high moisture shelled corn, the major concentrate component. Again, our objective was to determine if sugar supplementation would improve milk production and N utilization in dairy cows fed a diet containing alfalfa silage as the major forage.

Materials and Methods

Eight primiparous and 40 multiparous (8 with rumen cannulae) Holsteins were fed TMR containing (DM basis) 40% alfalfa silage, 20% corn silage, and 40% concentrate without molasses (Table 1) for a 2-wk standardization period. Production of milk and milk components during this period was used as a covariate adjustment for production during the subsequent experimental period. After standardization, cows were blocked by parity and days in milk to 12 blocks of four (two blocks with rumen cannulae) and within each group were randomly assigned to one of four TMR ranging from 29 to 17% high moisture shelled corn and from 0 to 12% dried molasses (Table 1). Cows were fed their assigned experimental diets for 8-wk. All cows received biweekly injections of BST. Milk yield was measured at each milking; DM intake was determined daily. Yield of milk components was determined from milk samples taken at both daily milkings one day during the covariate and every 2-wk during the experimental period. Spot urine and fecal samples were collected from all cows on the last day of wk-4 and wk-8. Ruminal metabolites also were measured on the last day of wk-4 and wk-8 in the eight cannulated cows. Statistical analysis was done using proc GLM in SAS. The statistical model for each milk component included block (n = 12) and covariate value, and for urinary and fecal traits, for ruminal metabolites, and for apparent digestibility included block and sampling period.

Results and Discussion

The four experimental diets averaged 18.0% CP (Table 1), somewhat higher than anticipated, because the alfalfa silage contained about 22% CP. Experimental diets also contained an average 29% NDF and 42% nonfiber carbohydrates, indicating that there was sufficient energy content to support about 40 kg/d of milk production. Nonstructural carbohydrate analysis of the diets indicated that replacing high moisture corn by adding from 0 to 12% dried molasses (in 4% increments) increased dietary sugars by 4.6%. However, there was a 8% decrease in dietary nonstructural carbohydrates over this range due to starch declining more than total sugars increased (Table 1). This was because the dried molasses fed in this trial was produced using a fibrous carrier and contained about 22% ADF. Thus, unlike the earlier study where sucrose replaced equal amounts of corn starch, results from the present trial were confounded by a small step-wise increase in dietary fiber with each increment of dietary sugar. Despite this confounding effect, there was a linear increase in DM intake, and significant quadratic responses in the yields of FCM and fat, with increasing dietary sugar (Table 2). The maximum of the quadratic responses for FCM and fat occurred at an average of 3.5% dried molasses added to the diet. There were trends ($P \leq 0.11$) for linear increases in yield of protein and true protein, and a trend ($P = 0.11$) for a quadratic response in protein yield, with increasing dietary sugar. However, because significant increases in milk or protein yield did not accompany the increased DM intake, there were significant linear declines in milk/DM intake and milk N/N intake with increasing dietary sugar. The linear decreases in urinary excretion of urea N and total N were not consistent with the observed reduction in N efficiency with added dietary sugar.

There was a significant quadratic effect of sugar addition to the diet on ruminal ammonia (Table 3); the minimum ammonia concentration occurred at 6.1% added dried molasses—corresponding to about 2.3% added total sugars. Feeding dried molasses also gave a linear decline in branched-chain VFA. Reduced ruminal concentrations of both ammonia and branched-chain VFA suggested that sugar feeding stimulated microbial protein formation. Adding sugar to the diet had no effect on total VFA, or on molar proportions of acetate, propionate, or acetate: propionate ratio. However, molar proportion of butyrate was increased with sugar addition; this may explain our finding of increased fat secretion (Table 2). Although no effect was detected on ruminal butyrate in our previous study (Broderick, Luchini et al., USDFRC Res. Summaries, 2001), increased butyrate was observed in a number of trials in which sugar feeding also increased fat yield in lactating cows. Adding dried molasses to the diet gave linear increases in apparent DM and OM digestion, which indicated that, although dietary fiber was elevated, energy availability also was increased.

Summary and Conclusion

Incremental replacement of high moisture corn with dried molasses resulted in a linear increase in DM intake. Moreover, there were significant quadratic responses in yields of FCM and fat; maxima were found at about 3.5% dried molasses or about 1.4% added total sugars in the dietary DM. Significant reductions in urinary N excretion and in ruminal concentrations of ammonia and branched-chain VFA suggested there was improved microbial protein formation with sugar supplementation; however, there were no effects on the yield of milk, protein, lactose, or SNF under the conditions of this trial. Overall, the major responses to supplementing dietary sugar as dried molasses were improved feed intake and fat production.

Table 1. Composition of diets[1].

Item	Covariate	Diet A	Diet B	Diet C	Diet D
Dried molasses, % DM	. . .	0	4	8	12
HMSC, % DM	31	29	25	21	17
			% of DM		
Alfalfa Silage	40.0	40.0	40.0	40.0	40.0
Corn Silage	20.0	20.0	20.0	20.0	20.0
High moisture shelled corn	30.6	29.0	25.0	21.0	17.0
Solvent soybean meal	4.0	8.0	8.0	8.0	8.0
Roasted soybeans	4.4	0.0	0.0	0.0	0.0
Fat (Energy Booster®)	0.0	2.0	2.0	2.0	2.0
Sodium bicarbonate	0.4	0.4	0.4	0.4	0.4
Dicalcium phosphate	0.2	0.2	0.2	0.2	0.2
Salt	0.3	0.3	0.3	0.3	0.3
Trace minerals and vitamins[2]	0.1	0.1	0.1	0.1	0.1
Dried Molasses	0.0	0.0	4.0	8.0	12.0
Chemical composition					
CP	18.1	18.1	17.9	17.9	18.1
NDF	30.5	28.2	29.1	29.2	29.3
ADF	20.5	18.3	19.3	19.6	20.0
NFC	39.6	42.8	41.4	40.7	41.2
Fat	4.1	4.3	4.2	4.7	3.8
NSC[3]	31.6	33.9	32.6	30.8	30.4
Starch[3]	29.4	31.3	28.4	25.2	23.2
Sugar[3]	2.2	2.6	4.2	5.6	7.2
Sugar increment[4]	. . .	0.0	1.6	3.0	4.6

[1]HMSC = High moisture shelled corn; NFC = nonfiber carbohydrate; NSC = nonstructural carbohydrate.

[2]Provided 56 mg of Zn, 46 mg of Mn, 22 mg of Fe, 12 mg of Cu, 0.9 mg of I, 0.4 mg of Co, 0.3 mg of Se, 6440 IU of vitamin A, 2000 IU of vitamin D, and 16 IU of vitamin E/kg of DM.

[3]Nonstructural carbohydrates determined by Tammy Miller Webster of West Virginia University.

[4]Incremental sugar addition to diets B, C, and D determined by chemical analysis.

Table 2. Effect of replacing dietary high moisture corn with dried molasses on intake, weight gain, production, and urinary excretion in lactating dairy cows.

	Diets					Probability[2]	
Item	A	B	C	D	SE[1]	Linear	Quadratic
Dried molasses, % DM	0	4	8	12			
HMSC, % DM	29	25	21	17			
DM intake, kg/d	25.1	25.8	26.2	26.0	0.3	0.04	0.16
Weight gain, kg/d	0.41	0.16	0.36	0.19	0.09	0.27	0.65
Milk, kg/d	38.0	37.5	38.9	36.7	0.6	0.34	0.16
Milk/DM intake	1.51	1.46	1.48	1.43	0.02	0.03	0.99
Milk N/N intake	0.255	0.244	0.254	0.231	0.006	0.02	0.29
3.5% FCM, kg/d	41.4	42.0	43.4	39.5	1.0	0.33	0.04
Fat, %	4.07	4.26	4.11	4.06	0.10	0.65	0.24
Fat, kg/d	1.54	1.59	1.63	1.47	0.04	0.34	0.03
Protein, %	3.12	3.09	3.11	3.04	0.04	0.29	0.61
Protein, kg/d	1.19	1.14	1.23	1.09	0.03	0.10	0.11
True protein, %	3.00	2.98	2.98	2.92	0.04	0.20	0.55
True protein, kg/d	1.14	1.09	1.17	1.05	0.03	0.11	0.19
SNF, %	8.85	8.84	8.85	8.80	0.04	0.48	0.62
SNF, kg/d	3.38	3.30	3.49	3.18	0.08	0.25	0.18
Milk urea N, mg/dl	15.3	14.4	15.0	14.7	0.3	0.52	0.37
Urine volume, l/d	32.5	33.0	32.1	33.1	0.9	0.83	0.78
Urinary urea-N, g/d	175	154	171	146	5	< 0.01	0.69
Urinary total-N, g/d	324	295	321	288	8	0.04	0.80
Urea-N/total-N	0.554	0.535	0.546	0.519	0.015	0.17	0.82

Least square means.
[1]SE = Standard error.
[2]Probability of a significant linear or quadratic effect of the dietary level of dried molasses.

Table 3. Effect of replacing dietary high moisture corn with dried molasses on ruminal pH and metabolites and on nutrient digestibility in lactating dairy cows.

Item	Diets				SE[1]	Probability[2]	
	A	B	C	D		Linear	Quadratic
Dried molasses, % DM	0	4	8	12			
HMSC, % DM	29	25	21	17			
Rumen metabolism							
pH	5.81	5.88	5.79	5.91	0.09	0.59	0.79
Ammonia-N, mg/dl	11.33	9.12	10.71	10.67	0.46	0.86	0.05
Total AA, mM	1.80	1.34	2.19	2.01	0.42	0.46	0.76
Total VFA, mM	129.4	129.4	135.8	131.6	4.1	0.50	0.63
VFA molar proportions, mol/100 mol							
Acetate	62.2	63.6	62.0	64.1	1.0	0.38	0.74
Propionate	22.0	20.8	21.9	19.8	1.0	0.26	0.67
A: P ratio	2.90	3.13	2.88	3.28	0.18	0.30	0.63
Butyrate	11.5	11.3	11.9	12.0	0.2	0.10	0.52
Branched-chain VFA	2.62	2.83	2.49	2.52	0.06	0.05	0.19
Valerate	1.74	1.55	1.73	1.64	0.07	0.69	0.52
Digestibility, %							
DM	57.7	58.9	60.0	61.9	0.7	< 0.01	0.65
OM	58.5	60.2	61.2	63.2	0.8	< 0.01	0.80
NDF	39.2	38.7	38.7	40.5	0.8	0.27	0.17
ADF	41.8	39.9	38.9	39.9	0.8	0.07	0.09
N	56.9	55.5	57.8	57.6	1.2	0.41	0.65
Fecal excretion, kg/d							
N, g/d	316	323	328	307	12	0.71	0.24

[1]SE = Standard error.

[2]Probability of a significant linear or quadratic effect of the dietary level of dried molasses.

Effect of Feeding Alfalfa or Red Clover Silage to Lactating Dairy Cows With or Without Corn Silage

G.A. Broderick and R.P. Walgenbach

Introduction

The large amounts of NPN in alfalfa silage (AS) substantially reduce its protein efficiency when fed to lactating dairy cows. Researchers at the Dairy Forage Center (Jones et al., J. Sci. Food Agric. 67:329-333, 1995) found that an enzyme, polyphenol oxidase, acts in red clover silage (RCS) to produce a forage with less NPN than AS. A previous feeding study (Broderick and Maigan, 1996 USDFRC Res. Sum.) showed that, although DMI was greater on AS, milk yield was similar on AS and RCS, and N-efficiency greater on RCS. Other consistent findings have been lower CP content and greater DM and fiber digestibility for RCS. The present trial assessed the effects of feeding AS versus RCS, with or without dietary corn silage (CS).

Materials and Methods

Alfalfa silage was harvested from first cutting beginning on May 20 and ending on May 28, 1998; RCS was harvested from two cuttings taken on June 8, 1998 (first cutting) and July 14, 1998 (second cutting). Forages were field-wilted, chopped, and ensiled in two bunker silos (AS) or in two plastic bags (RCS). Forages were cut using a conventional mower conditioner, wilted to about 35% DM (range 26 to 41% DM), chopped to a theoretical length of 2.9 cm, and ensiled without additives. No forage was rained on during harvest. Diets (Table 1) were formulated to about 60 or 48% of DM from either AS or RCS; diets with 48% AS or RCS contained 12% CS. Half of the RCS DM on both RCS diets came from each cutting. Diets with 60% AS or RCS contained equal soybean meal (SBM); sufficient SBM was added to the 48% RCS diet to give an CP content equal to that in the 60% RCS and 48% AS diets. Twenty-four multiparous cows were randomly assigned to diets in six balanced 4 X 4 Latin squares. Diets were fed for 4-wk periods before switching (total 16 wk); production and composition data were collected in the third and fourth wk of each period. Apparent nutrient digestibility was estimated from fecal grab samples using indigestible ADF as internal marker. Statistical analysis was done using proc GLM in SAS.

Results and Discussion

Red clover silage contained less DM, NDF, and ADF than did AS but there was only a trend for CP in AS to be higher than in RCS (Table 1). As was observed in every trial comparing these two forages, NPN content was lower in RCS than AS: 40 versus 64% NPN in total N. Proportions of total N present as ammonia and free AA also were lower in RCS. The RCS contained about 2 percentage units more ADIN than AS (Table 1). As expected, greater CP in AS resulted in the 60% AS diet containing more CP than the other three diets, which averaged about 16.5% CP (Table 1).

Results from the lactation study are in Table 2. Cows ate more when fed AS than when fed RCS, with or without CS or supplemental SBM in the diet. Yields of milk, total protein, true protein, and SNF were not different among cows fed diets containing forage from AS, RCS, or AS + CS, regardless of CP level or DMI. Cows fed forage as RCS + CS (with additional SBM) actually yielded more milk, protein, true protein, and SNF than when fed the other three diets, despite lower feed intake than on either AS diet. This observation was at variance with the reduced yields that accompanied lower intakes on RCS in some of our earlier work (Broderick and Sterrenburg, 1996 USDFRC Res. Sum.). The RCS diets fed in those previous trials, although containing forage DM equal to that of the AS diets, contained less CP. Additional SBM in the RCS + CS diet provided both RDP and RUP and the greater protein yields may have reflected improved protein status. Earlier, we found that equalizing dietary CP by adding SBM gave rise to similar production on RCS as on AS (Broderick and Maigan, 1996 USDFRC Res. Sum.). Feed DM and N efficiencies were greater on both RCS diets than on the AS diets (Table 2). Although confounded by dietary CP level, MUN concentration was higher on the diet containing 60% AS than on the other three diets. We noted that MUN was lower on 60% RCS than on AS + CS or RCS + CS, despite its numerically greater CP (Table 1). However, DMI and N intake also were lowest on the RCS diet; earlier, excess N intake (total N intake - milk N secretion) was found to be nearly as well correlated to MUN as dietary CP concentration. Additionally, milk fat content averaged about 0.25 unit lower on the two RCS diets (Table 2). Previously, we observed lower milk fat content and yield when RCS replaced AS as dietary forage (Broderick and Sterrenburg, 1996 USDFRC Res. Sum.). However, milk fat content was in excess of 4%, quite high for Holsteins, and there was no effect of diet on fat yield ($P = 0.32$). Differences in feed efficiency were associated with large effects ($P < 0.01$) of diet on nutrient digestibility (Table 2). Apparent digestibility of DM, OM, NDF, ADF, and hemicellulose were highest on RCS, intermediate on RCS + CS, and lowest on the two AS diets. Replacing RCS with CS reduced apparent digestibilities but there was no effect when CS replaced dietary AS, suggesting that apparent digestibility of RCS nutrients exceeded that of CS but that digestibilities of AS and CS were comparable. Despite differences in DMI, intake of digestible OM was about equal across all diets, ranging from 14.5 to 14.9 kg/

d. This indicated that lower DMI on the RCS was due to its greater energy digestibility and cows ate to constant energy supply.

Summary and Conclusion

Relative to AS, RCS averaged two or more percentage units lower in CP, NDF, and ADF but had only 62% as much NPN (proportion of total N). When fed at equal proportions of diet, cows consumed less DM on RCS but similar digestible OM. Yields of milk, FCM, protein, and SNF were equal when RCS replaced AS at 60% of the diet, despite lower DMI. Supplementing the RCS + CS diet (in which CS replaced one-fifth of the forage) with enough SBM to increase CP to the level in the AS + CS diet increased yields of milk, total protein, true protein, and SNF. Replacing AS with RCS increased apparent digestibility of dietary nutrients and increased feed and N efficiencies. Utilization of both energy and CP in RCS exceeded that of AS. Greater nutrient digestibility and lower NPN content suggested that feeding RCS may result in lower environmental N losses than feeding AS.

Table 1. Composition of alfalfa and red clover silages and diets[1].

	Forage			
Item	AS	RCS	SE	*P* > F
DM, %	36.6	28.9	0.4	< 0.01
CP, % of DM	21.7	19.1	0.7	0.08
Ash, % of DM	10.5	11.5	0.3	0.13
NDF, % of DM	44.6	42.6	0.4	0.04
ADF, % of DM	35.6	32.9	0.4	0.02
Hemicellulose, % of DM	9.0	9.7	0.4	0.40
pH	4.70	4.54	0.09	0.35
NPN, % of total N	64.0	39.6	1.6	< 0.01
NH_3-N, % of total N	13.2	11.1	0.3	0.01
Total AA-N, % of total N	26.7	16.6	0.6	< 0.01
ADIN, % of total N	3.1	5.2	0.2	< 0.01

	Diet			
Item	AS	RCS	AS + CS	RCS + CS
	% of DM			
Alfalfa silage	60.5	. . .	48.3	. . .
Red clover silage	. . .	60.7	. . .	48.5
Corn silage	. . .	. . .	12.3	12.3
High moisture shelled corn	35.7	35.6	35.6	32.8
Solvent soybean meal	2.9	2.9	2.9	5.6
Dicalcium phosphate	0.5	0.5	0.5	0.5
Salt	0.3	0.3	0.3	0.3
Trace minerals and vitamins[2]	0.1	0.1	0.1	0.1
Chemical composition				
CP	18.4	16.6	16.5	16.3
NDF	32.0	31.3	32.1	31.7
ADF	24.1	22.7	22.7	21.8

[1]AS = alfalfa silage, RCS = red clover silage, CS = corn silage.

[2]Provided 56 mg of Zn, 46 mg of Mn, 22 mg of Fe, 12 mg of Cu, 0.9 mg of I, 0.4 mg of Co, 0.3 mg of Se, 6440 IU of vitamin A, 2000 IU of vitamin D, and 16 IU of vitamin E/kg of DM.

Table 2. Effect of feeding diets containing alfalfa silage (AS), red clover silage (RCS), or AS or RCS plus corn silage (CS), on production and digestibility in lactating dairy cows.

Item	Diets				SE[1]	$P > F$[2]
	AS	RCS	AS+CS	RCS+CS		
DMI, kg/d	23.5^{a}	21.8^{c}	23.8^{a}	22.8^{b}	0.2	<0.01
BW gain, kg/d	0.30	0.56	0.46	0.60	0.12	0.27
Milk, kg/d	30.4^{b}	30.4^{b}	30.3^{b}	31.7^{a}	0.3	0.02
3.5% FCM, kg/d	31.6	31.1	32.0	32.4	0.5	0.27
Fat, %	4.30^{a}	4.06^{b}	4.33^{a}	4.08^{b}	0.07	<0.01
Fat, kg/d	1.15	1.11	1.16	1.15	0.02	0.32
Protein, %	3.33	3.30	3.39	3.36	0.03	0.29
True protein, %	3.13	3.14	3.20	3.18	0.03	0.41
Protein, kg/d	0.89^{b}	0.90^{b}	0.91^{b}	0.95^{a}	0.01	<0.01
True protein, kg/d	0.83^{b}	0.86^{b}	0.86^{b}	0.90^{a}	0.01	<0.01
SNF, %	8.81	8.87	8.89	8.95	0.08	0.64
SNF, kg/d	2.35^{b}	2.43^{b}	2.39^{b}	2.54^{a}	0.03	<0.01
Milk/DMI	1.30^{b}	1.40^{a}	1.28^{b}	1.40^{a}	0.01	<0.01
Milk N/N intake	0.204^{c}	0.249^{a}	0.228^{b}	0.256^{a}	0.003	<0.01
Milk urea, mg N/dl	13.6^{a}	9.2^{d}	11.2^{b}	10.1^{c}	0.3	<0.01
Apparent digestibility, %						
DM	64.5^{c}	71.5^{a}	65.1^{c}	68.4^{b}	0.7	<0.01
OM	66.7^{c}	73.3^{a}	67.4^{c}	70.0^{b}	0.6	<0.01
NDF	44.1^{c}	55.3^{a}	44.3^{c}	49.8^{b}	0.7	<0.01
ADF	44.2^{c}	54.2^{a}	43.4^{c}	49.1^{b}	0.7	<0.01
Hemicellulose	43.9^{c}	58.0^{a}	46.3^{c}	51.3^{b}	1.1	<0.01
N	62.3	59.7	60.7	58.2	1.1	0.06

[a,b,c,d]Means within the same row without a common superscript differ ($P < 0.05$).
[1]SE = Standard error.
[2]Probability of a significant effect of diet.

Alfalfa Versus Red Clover Silage—Summary of Results From Five Feeding Studies With Lactating Dairy Cows

G.A. Broderick

Introduction

When ensiled, 50 to 60% of the CP in alfalfa typically is broken down to NPN. High levels of NPN depress protein utilization by lactating dairy cows. Red clover, a forage legume similar to alfalfa, forms less NPN in the silo. However, widespread use of red clover is limited by its lower yield per acre, poorer stand persistency, and slower field drying rates. If there were consistent advantages in efficiency of nutrient utilization for red clover, then research could be directed toward improving the agronomic characteristics of this forage. Over a number of years, five lactation trials were conducted at the Dairy Forage Center to determine the relative feeding value of alfalfa silage (AS) and red clover silage (RCS) for dairy cows. Although the trials had several different dietary treatments, each contained at least one direct comparison of AS to RCS fed at equal dietary DM. This report summarizes results of an analysis of the relative performance of cows fed AS or RCS at equal proportions of the diet over all five studies.

Materials and Methods

Results were from five Latin square feeding studies that are already published (Broderick et al., J. Dairy Sci. 83: 1543-1551, 2000; Broderick et al., J. Dairy Sci. 84:1728-1737, 2001). Data were obtained by feeding AS and RCS harvested at various cuttings during 1992 through 1998. Generally, the forages were cut using conventional mower conditioners, field wilted to 30 to 50% DM, chopped to a theoretical length of 2.9 cm, and ensiled without additives in either upright concrete stave silos or in plastic bags. Diets (Table 1) were formulated to contain about 60% DM from either AS or RCS; overall mean dietary compositions were weighted for the number of dairy cows used in each trial. A total of 104 animal observations were made on each diet. Mean soybean meal contents on the two diets were not the same because more soybean meal was fed with RCS in one of the five trials to equalize dietary CP. Data from all five trials were analyzed using proc GLM in SAS with a model that included period(trial), trial, forage, and forage by trial interaction. Least square means are reported.

Results and Discussion

Consistently, red clover silage contained less CP and ADF, and more hemicellulose, than did AS (Table 1). There was a trend for forage pH to be lower in RCS, suggesting this silage fermented more rapidly. The NPN content of RCS was lower than AS: 36 versus 53% of total N; proportions of total N present as ammonia and free AA also were lower in RCS. These differences were observed in all five trials. The RCS contained 1.6 percentage units more ADIN than AS; formation of ADIN may be related to the action of polyphenol oxidase, the plant enzyme that accounts for the lower NPN formation in RCS. As expected, the greater CP in AS resulted in those diets containing more CP than the RCS diets (Table 1).

Least square means from the five lactation studies are in Table 2. Cows consistently ate more when fed AS than when fed RCS; overall DMI was 1.5 kg/d lower on RCS. Yield responses due to silage source were variable among trials. For example, milk yield was greater on AS in two trials, not different in two trials, and greater on RCS in one trial. However, there were no significant overall effects of silage source ($P \geq 0.16$) on yields of milk, FCM, protein, or SNF despite the differences in feed intake. There were trends ($P \sim 0.10$) for greater weight gain and lower fat yield on RCS than AS; additionally, milk fat content averaged about 0.15 unit lower ($P = 0.05$) on RCS diets. These results suggested that replacing dietary AS with RCS may result in the redirecting of fat synthesis away from mammary secretion to body deposition. Blood glucose concentration was unaffected by forage source, indicating there were no overt differences in insulin secretion on the two diets. Efficiency of capture of feed N in milk was greater ($P < 0.01$), and both milk and blood urea concentrations were lower ($P < 0.01$), on RCS diets. Although these factors were confounded by higher dietary CP on AS (Table 1), they suggested that N losses to the environment may be reduced through feeding of RCS or other low NPN silages. A lactation in which a cow produces 10,000 kg of milk with 3.2% protein would result in secretion of (320/6.38) = 50 kg of milk N. Increasing N efficiency from 0.236 to 0.271 would reduce N excretion from 162 to 135 kg N/lactation. Feed DM efficiency also tended to be greater (P = 0.10) on RCS. The difference in feed DM efficiency was associated with large effects of forage on nutrient digestibility. Apparent digestibility of DM, OM, NDF, ADF, and hemicellulose all were higher ($P < 0.01$) on RCS than on AS. Moreover, replacing AS with RCS reduced ($P < 0.01$) estimated excretion of fecal DM by 19%. A reduction of this magnitude, if milk yield were not altered, would have the positive effect of substantially decreasing the amount of manure solids that would have to be handled on the dairy farm.

The NEL requirements for maintenance, BW gain, and milk output (based on observed fat and SNF content) were used to compute forage energy values (Table 3). The NEL requirements for mean production were nearly identical (average 32.4 Mcal/d). Subtracting the NEL contributed from the concentrate portion of the diet yielded estimates of NEL supplied by AS and RCS. Per unit DM, AS was computed to have 1.14 Mcal/kg, versus 1.29 Mcal/kg for RCS, indicating that RCS contained 13% more NEL than AS, despite the two forages having equal NDF contents (Table 1). An NEL content of 1.88 Mcal/kg for the concentrate portion of the ration (Table 3) corresponds to a TDN value of 76% (NRC, 2001). If TDN is assumed equal to OM digestibility, OM digestibilities of 55.3 and 63.0% may be computed, respectively, for the AS and RCS forages in these diets, indicating a relative value for RCS that is 14% greater than AS. Despite differences in DMI, intake of digestible OM was nearly identical on the two silages: 14.4 kg/d on AS and 14.5 kg/d on RCS. This indicated that the lower DMI on RCS diets was due to greater energy digestibility and cows ate to constant energy supply.

Summary and Conclusion

Over five different lactation trials, RCS averaged 3.0 and 1.7 percentage units lower in, respectively, CP and ADF and contained only 67% as much NPN (as a proportion of total N). When fed at equal amounts of the diet, cows consumed less DM on RCS than on AS but equal amounts of digestible OM. Yields of milk, FCM, protein, and SNF were equal when RCS replaced AS, despite the lower DMI. Milk fat content was lower, and there were tendencies for greater weight gain and lower fat yield, when RCS replaced AS in the diet. Replacing AS with RCS increased apparent digestibility of dietary DM, OM, NDF, ADF and hemicellulose and N efficiency and tended to increase feed efficiency. Utilization of both energy and CP in RCS exceeded that of AS. Greater nutrient digestibilities and lower NPN content suggested that feeding RCS would result in improved nutrient efficiencies and lower environmental N losses than feeding AS.

Table 1. Composition of alfalfa and red clover silages and diets.

	Forage			
Item	Alfalfa silage	Red clover silage	SE[1]	$P > F$[2]
DM, %	41.3	40.3	1.2	0.55
CP, % of DM	20.9	17.9	0.4	<0.01
Ash, % of DM	11.2	10.8	0.3	0.37
NDF, % of DM	43.3	43.0	0.5	0.63
ADF, % of DM	33.8	32.1	0.4	<0.01
Hemicellulose, % of DM	9.5	10.8	0.2	<0.01
pH	4.62	4.49	0.05	0.07
NPN, % of total N	53.1	35.8	1.0	<0.01
NH_3-N, % of total N	29.5	17.7	0.7	<0.01
Total AA-N, % of total N	9.5	7.6	0.4	<0.01
ADIN, % of total N	3.5	5.1	0.2	<0.01

	Diet	
Item	Alfalfa silage	Red clover silage
	% of DM	
Alfalfa silage	62.7	. . .
Red clover silage	. . .	62.4
High moisture corn	34.6	34.0
Solvent soybean meal	1.6	2.4
Dicalcium phosphate	0.6	0.6
Salt	0.3	0.3
Trace minerals and vitamins[3]	0.2	0.2
Chemical composition		
CP	17.7	15.8
NDF	33	32
ADF	24	22

[1]SE = Standard error.

[2]Probability of a significant effect of forage source.

[3]Three different but typical trace mineral and vitamin supplements were fed over the course of the five trials.

Table 2. Effect of feeding diets containing either alfalfa silage or red clover silage on production and digestibility in lactating dairy cows.

Item	Diet		SE[1]	$P > F$[2]
	Alfalfa silage	Red clover silage		
DMI, kg/d	22.9	21.4	0.3	<0.01
BW gain, kg/d	0.02	0.20	0.07	0.08
Milk, kg/d	32.0	31.2	0.5	0.27
3.5% FCM, kg/d	32.0	31.0	0.5	0.16
Fat, %	3.66	3.51	0.06	0.05
Fat, kg/d	1.12	1.08	0.02	0.10
Protein, %	3.03	3.00	0.02	0.29
Protein, kg/d	0.93	0.91	0.01	0.26
Lactose, %	4.78	4.81	0.02	0.27
Lactose, kg/d	1.49	1.48	0.02	0.68
SNF, %	8.53	8.56	0.05	0.59
SNF, kg/d	2.65	2.62	0.04	0.50
Milk/DMI	1.42	1.47	0.02	0.10
Milk N/N intake	0.236	0.271	0.003	<0.01
Milk urea, mg N/dl	12.5	8.7	0.2	<0.01
Blood urea, mg N/dl	14.2	9.3	0.3	<0.01
Blood glucose, mg/dl	52.8	52.7	0.5	0.89
Fecal DM, kg/d	8.80	7.14	0.15	<0.01
Apparent digestibility, %				
DM	61.5	66.6	0.7	<0.01
OM	63.0	67.9	0.6	<0.01
NDF	43.1	52.5	0.7	<0.01
ADF	44.5	52.2	0.7	<0.01
Hemicellulose	38.9	52.3	1.1	<0.01
N	59.1	55.2	1.1	<0.01

[1]SE = Standard error.
[2]Probability of a significant effect of forage source.

Table 3. The NEL contents of alfalfa silage and red clover silage estimated from overall mean intake and production data.[1]

Item	Silage source	
	Alfalfa	Red clover
Dietary silage, % of DM	62.7	62.4
Dietary concentrate, % of DM	37.3	37.6
NEL requirement, Mcal/d[2]		
Maintenance	9.7	9.7
BW gain	0.1	1.0
Milk output	22.6	21.7
Total requirement, Mcal/d	32.5	32.4
Total DMI, kg/d	22.9	21.4
Concentrate DMI, kg/d	8.5	8.0
Concentrate NEL,[3] Mcal/kg DM	1.88	1.88
Concentrate NEL, Mcal/d	16.0	15.1
NEL from Silage,[4] Mcal/d	16.5	17.3
Silage DMI, kg/d	14.4	13.4
Silage NEL, Mcal/kg DM	1.14	1.29
Red clover/Alfalfa, %		113

[1]Diet composition data are means from Table 1 and intake and production data are least square means from Table 2.

[2]NEL (Mcal/d) requirements computed: maintenance = $0.08 \times BW^{0.75}$ (mean BW = 601 kg), gain = 5.12 x BW gain, and milk output = Milk x (0.09464 x % fat + 0.049 x % SNF - 0.0564) (NRC, 2001).

[3]Mean NEL contents of dietary concentrate in the trials computed from NRC (2001) tables.

[4]Total NEL requirement minus concentrate NEL intake.

Effect of Replacing Dietary Starch With Sucrose on Milk Production in Lactating Dairy Cows

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Introduction

Diets based on alfalfa silage and similar hay-crop silages contain high levels of NPN and other sources of rumen-degraded protein (RDP). On such diets, ruminal carbohydrate and protein fermentation often are out of synchrony—that is, the rate of energy fermentation is too slow to allow ruminal organisms to synthesize protein from rapidly available RDP. In these circumstances, increasing the rate of carbohydrate fermentation may lead to more effective capture of RDP and improved supply of absorbable protein to the dairy cow. Sugars are more rapidly fermented in the rumen than are most sources of starch, suggesting that sugars could serve as effective supplements on alfalfa silage diets. Moreover, the Cornell model suggests that the organisms in the ruminal liquid phase that utilize soluble sugars can contribute proportionately more microbial protein than the organisms that ferment starches and other nonstructural carbohydrates. A feeding study was conducted to determine if replacing dietary starch with sucrose would improve milk production and N utilization in dairy cows fed a diet containing alfalfa silage as its major forage.

Materials and Methods

Two sets of 24 Holstein cows (mean = 41 kg/d of milk) were fed a TMR containing (DM basis) 40% alfalfa silage, 20% corn silage, 7.5% corn starch, and 32.5% other concentrate ingredients (Table 1) for a 2-wk standardization period. Production of milk and milk components during this period were used as a covariate adjustment for production during the subsequent experimental periods. After standardization, cows in each set of 24 were blocked by days in milk into six groups of four cows and randomly assigned to one of four TMR ranging from 7.5 to 0% corn starch and from 0 to 7.5% sucrose (Table 1). Cows were fed their assigned experimental diets for 8-wk. Milk yield was measured at each milking; DM intake was determined daily. Yield of milk components was determined from milk samples taken at both daily milkings one day during the covariate and every 2-wk during the experimental period. Statistical analysis was done using proc GLM in SAS. The statistical model included period (n = 2), block (n = 12), and covariate yield of each milk component. Four ruminally cannulated cows were assigned to a 4x4 Latin square trial with 4-wk periods that was superimposed over the two 8-wk experimental phases of the larger lactation trial. Ruminal metabolites were measured on the last day of each period and the results analyzed using proc GLM in SAS.

Results and Discussion

The four experimental diets ranged from 16.6 to 16.9% CP, from 29 to 30% NDF, and from 43 to 44% nonfiber carbohydrates (Table 1). Moreover, nonstructural carbohydrate analysis of the diets indicated that the target increments of sugar addition, 2.5, 5.0 and 7.5% were very nearly reached by sucrose replacement of dietary corn starch (Table 1). Generally, there was little effect of sucrose supplementation on production. Although DM intake was increased linearly when sucrose replaced dietary starch, there was no effect on body weight gain or on yield of milk, protein, lactose, and SNF (Table 2). Because milk and protein yield were not increased, despite increased intake, there were linear reductions in DM and N efficiency with sucrose addition to the diet. However, there was a linear response in both milk fat content and milk fat yield when sucrose replaced dietary corn starch. The response of milk fat content was striking in that the increase in these Holsteins was from 3.8%

on 0-sucrose to nearly 4.2% on 7.5% sucrose diet. Graded levels of sucrose were added to the diet in an attempt to identify points of maximum response to sugar supplementation. However, there were no quadratic responses ($P \geq 0.15$) in this trial and this objective could not be met.

There were small but significant effects on some ruminal metabolites with incremental replacement of dietary corn starch with sucrose (Table 3). Adding sugar to the diet increased the molar proportion of propionate in total VFA and reduced molar proportions of branched chain VFA (the VFA produced from catabolism of the branched chain AA). Reduced branched chain VFA, plus trends ($P \leq 0.17$) for lower ruminal concentrations of NH_3 and total AA, suggested that there may have been greater microbial uptake of the products from RDP with sugar addition to the diet (Table 3). Feeding sucrose has been reported to stimulate milk fat secretion by increasing butyrate production in the rumen. As mentioned earlier, milk fat secretion was increased by sucrose feeding (Table 2); however, there was no effect on molar proportions of butyrate in total VFA in this trial. It is possible that ruminal butyrate production may have altered without apparent change in butyrate concentrations. Because there are only 95% as many 6-carbon sugars per unit weight in the disaccharide sucrose as in pure starch, replacing dietary corn starch with sucrose would lead to a small dilution of dietary energy. However, this effect would have been small: we estimated that the non-fat NEL of the ration decreased from 1.63 to 1.62 Mcal/kg of DM in going from 7.5% starch and 0 sucrose to 0 starch and 7.5% sucrose.

Table 1. Composition of diets[1].

Item	Covariate	Diet A	Diet B	Diet C	Diet E
			% of DM		
Alfalfa Silage	40.0	40.0	40.0	40.0	40.0
Corn Silage	20.0	20.0	20.0	20.0	20.0
High moisture shelled corn	20.5	20.5	20.5	20.5	20.5
Solvent soybean meal	6.6	9.0	9.0	9.0	9.0
Roasted soybeans	3.0	0.0	0.0	0.0	0.0
Fat (Energy Booster®)	1.4	2.0	2.0	2.0	2.0
Sodium bicarbonate	0.4	0.4	0.4	0.4	0.4
Dicalcium phosphate	0.2	0.2	0.2	0.2	0.2
Salt	0.3	0.3	0.3	0.3	0.3
Trace minerals and vitamins[2]	0.1	0.1	0.1	0.1	0.1
Corn Starch	7.5	7.5	5.0	2.5	0.0
Sucrose	0.0	0.0	2.5	5.0	7.5
Chemical composition					
CP	16.8	16.6	16.7	16.8	16.9
NDF	30.0	30.0	29.2	29.6	29.6
ADF	19.8	20.7	20.0	20.8	20.5
NFC	42.3	42.7	43.7	42.6	42.8
NDIN	3.5	3.0	3.3	3.3	2.8
ADIN	1.6	1.7	2.0	1.8	1.7
Fat	4.6	4.0	4.0	4.0	4.0
NSC[3]	25.4	30.9	32.5	31.6	31.5
Starch[3]	22.9	28.2	27.4	24.5	21.5
Sugar[3]	2.6	2.7	5.1	7.1	10.0
Sugar increment[4]	. . .	0.0	2.4	4.4	7.3

[1]ADIN = Acid detergent insoluble N; NDIN = neutral detergent insoluble N; NFC = nonfiber carbohydrate; NSC = nonstructural carbohydrate.

[2]Provided 56 mg of Zn, 46 mg of Mn, 22 mg of Fe, 12 mg of Cu, 0.9 mg of I, 0.4 mg of Co, 0.3 mg of Se, 6440 IU of vitamin A, 2000 IU of vitamin D, and 16 IU of vitamin E/kg of DM.

[3]Nonstructural carbohydrates determined by Tammy Miller Webster of West Virginia University.

[4]Incremental sugar addition to diets B, C, and D determined by chemical analysis.

Summary and Conclusion

Incremental replacement of dietary corn starch with sucrose resulted in a linear increase in DM intake but had no effect on the yield of milk, protein, lactose, or SNF. However, there were significant linear increases in milk fat content and yield with elevated dietary sugar. Small changes in ruminal metabolite concentrations were consistent with improved utilization of RDP when sucrose was added to a high quality lactation diet containing 40% alfalfa silage. Overall, effects of dietary sugar addition were confined to improved intake and fat production.

Table 2. Effect of replacing dietary corn starch with sucrose on intake, weight gain, and production in lactating dairy cows.

Item	Diets A	B	C	D	SE[1]	Probability[2] Linear	Quadratic
Sucrose, % of DM	0	2.5	5.0	7.5			
Starch, % of DM	7.5	5.0	2.5	0			
DM intake, kg/d	24.5	25.6	26.0	26.0	0.4	0.01	0.17
Weight gain, kg/d	0.34	0.53	0.40	0.47	0.12	0.61	0.62
Milk, kg/d	38.9	40.4	40.0	39.4	0.7	0.74	0.15
3.5% FCM, kg/d	40.5	42.2	43.9	43.2	1.3	0.11	0.38
Fat, %	3.81	3.82	4.07	4.16	0.11	0.01	0.73
Fat, kg/d	1.47	1.53	1.65	1.62	0.06	0.05	0.47
Protein, %	3.24	3.22	3.27	3.30	0.04	0.23	0.54
Protein, kg/d	1.24	1.28	1.29	1.28	0.03	0.35	0.36
Lactose, %	4.75	4.74	4.77	4.74	0.04	0.95	0.90
Lactose, kg/d	1.84	1.91	1.90	1.85	0.06	0.95	0.37
SNF, %	8.76	8.76	8.87	8.82	0.06	0.34	0.68
SNF, kg/d	3.38	3.51	3.51	3.44	0.10	0.69	0.32
Milk/DM intake	1.60	1.58	1.54	1.52	0.03	0.02	0.96
Milk N/N intake	0.312	0.291	0.291	0.285	0.01	0.01	0.26

Least square means.
[1]SE = Standard error.
[2]Probability of a significant linear or quadratic effect of sucrose level in the diet.

Table 3. Effect of replacing dietary corn starch with sucrose on ruminal pH and metabolites in lactating dairy cows.

Item	Diets A	B	C	D	SE[1]	*P* > F[1]
Sucrose, % of DM	0	2.5	5.0	7.5		
Starch, % of DM	7.5	5.0	2.5	0		
pH	6.19	6.16	6.19	6.21	0.05	0.88
NH_3-N, mg/dl	6.93	6.87	6.21	5.75	0.34	0.14
Total AA, mM	4.32	3.46	3.31	3.61	0.29	0.17
Total VFA, mM	105.8	106.8	111.6	103.7	4.2	0.61
Molar proportion, mol/100 mol						
Acetate	60.9	60.8	60.1	60.4	0.7	0.87
Propionate	20.2[b]	21.1[ab]	21.4[ab]	22.0[a]	0.3	0.04
A:P ratio	3.06	2.93	2.87	2.82	0.07	0.16
Butyrate	14.3	13.1	13.5	14.0	0.6	0.63
Branched-chain VFA	3.7[a]	3.3[a]	3.1[ab]	2.4[b]	0.2	0.02
Valerate	2.0	2.4	2.5	2.0	0.2	0.26

[a,b]Least square means within the same row with different superscripts are different ($P < 0.05$).
[1]SE = Standard error.
[2]Probability of a significant effect of diet.

Effects of Feeding Dairy Cows Protein Supplements of Varying Ruminal Degradability
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Introduction

Optimizing the balance between microbial protein synthesis and degradation in the rumen will reduce ruminant N excretion and, consequently, N losses to the environment. Several newly devised systems of ruminant ration formulation require rates of ruminal protein degradation in their application. Lack of reliable information on, and methods to determine, protein degradation rates has led to the common practice of over-feeding protein to dairy cows to avoid possible amino acid shortages. Protein standards of known in vivo degradabilities are needed to develop methods for determining ruminal degradability. An omasal canal sampling technique developed by Huhtanen et al. (J. Anim. Sci. 75:1380-1392,1997) and modified by Ahvenjarvi et al. (Brit. J. Nutr. 83:67-77, 2000) has proven to be an accurate and less invasive approach for measuring nutrient flows out of the rumen. Our objectives were: 1) to quantify the effects of feeding protein supplements with differing ruminal degradabilities on milk production, and 2) to use the omasal sampling technique to quantify in vivo rates and extents of ruminal degradation of four protein supplements.

Materials and Methods

Twenty-five (ten with ruminal cannulas) lactating Holstein cows were assigned to five, 5 x 5 Latin squares and fed TMR containing rolled corn silage, alfalfa silage, rolled high moisture shelled corn, protein supplement, urea, and minerals. Diets (Table 1) differed in source of protein supplement: diet A (control; no supplement); diet B (solvent soybean meal; SSBM); diet C [expeller soybean meal (SoyPlus ® West Central Coop., Ralston, IA); ESBM], diet D (blood meal; BM); and diet E (corn gluten meal; CGM). Experimental periods lasted 21 d , consisting of 12-d for adaptation and 9-d for sample collection. Body weights were measured at the end of each period. Milk yield was recorded at all daily milkings. Milk was sampled at consecutive milkings on d-13 and d-20 of each period and analyzed for fat, protein, and SNF by infrared analysis (AgSource, Menomonie, WI). A triple marker technique using separate markers for liquid (Co-EDTA), small particle (Yb), and large particle (indigestible NDF) phases was used to quantify omasal digesta flow out of the rumen. The alternating vacuum and pressure system originally developed by Huhtanen et al. (1997) and Ahvenjarvi et al. (2000) was used to collect digesta from the omasal canal. Purines were used to distinguish between total protein AA N (TAAN) from microbial protein and rumen undegraded feed protein (RUP). Ruminal contents also were collected from all cannulated cows after Co-EDTA and Yb infusions were stopped. Samples were analyzed for marker decay (ruminal passage rates) and for VFA, ammonia and total free AA. Statistical analysis was done using proc mixed in SAS.

Results and Discussion

Cows fed control diet A consumed 1.1 to 2.1 kg/d less DM than cows fed the other diets; DMI in cows fed diet C (ESBM supplemented) was higher than that in cows fed diet D (BM) but not different from cows fed diets B (SSBM) and E (CGM) (Table 2). Although daily BW gain was not different among diets, cows fed basal diet A had the lowest yields of milk, FCM, fat, protein, and SNF, partly as a result of having the lowest DMI. Cows fed diets C (ESBM) and E (CGM) produced 1.4 and 1.9 kg/d more milk than cows fed diet B (SSBM). Milk yield of cows fed diet D (BM) was intermediate; however, of the four protein supplemented diets, DMI was numerically lowest when

BM was fed. Yields of fat, protein, and SNF were not different among diets B, C, D, and E. Milk concentrations of fat, protein, and SNF were not altered by diet. Neither ruminal pH or total free AA concentrations were affected by diet (Table 2). However, ruminal ammonia was lowest on diets A (control) and E (CGM), highest on diet B (SSBM), and intermediate on diets C (ESBM) and D (BM). Lower CP intake and higher intake of high moisture corn may have reduced ammonia concentration and enhanced microbial NPN utilization on diet A. Higher ruminal ammonia on diet B is consistent with greater ruminal degradation of SSBM. Cows fed diets B and D had higher ruminal concentrations of total VFA than cows fed diets A and E ($P < 0.05$), with cows fed diet C being intermediate (Table 2) . Ruminal VFA concentrations are the result of production and absorption and do not necessarily reflect fermentation rates. Moreover, the range of total VFA concentrations was narrow, from only 110 to 119 m*M*, and these small changes may not be biologically important. Although there were statistically significant effects of diet on ruminal acetate and propionate concentrations, differences were small and there was no effect on acetate: propionate ratio. Ruminal isobutyrate was highest on diet B (SSBM), lowest on basal diet A and diets D (BM) and E (CGM), and intermediate on diet C (ESBM). Isobutyrate partly comes from ruminal catabolism of valine and lower concentrations may be related to reduced true protein degradation. Neither ruminal OM nor NDF digestibility was altered by diet.

Estimates of extent of ruminal escape of the four protein supplements based on omasal TAAN flows are in Table 3. Ruminal escapes for SSBM, ESBM, BM, and CGM were, respectively, 35, 51, 62, and 53% based on TAAN flow. The differences in milk yields (Table 2) were consistent with these estimates of RUP. That greater omasal TAAN flow (due to greater ruminal BM escape) did not give rise to greater protein yield may be related to differences among the proteins in RUP digestibility. The NRC (2001) assigned intestinal digestibilities of 93, 93, 80, and 94% for the RUP from SSBM, ESBM, BM, and CGM, respectively. Extent of protein degradation is the resultant of the rates of passage and degradation, and both must be known to estimate the amount of protein escaping rumen degradation. The particle sizes of the protein concentrates were such that they would have been expected to pass with the small particle (Yb) phase. The NPN (fraction A) and ADIN (fraction C) contents were small and proportions of intact protein (fraction B) ranged from 98.4 to 99.5% for the four proteins (Table 3). In vivo degradation rates for these fractions B were computed using both the observed Yb passage rates (mean rate = 0.14/h) and assuming a passage rate of 0.06/h. These rates of degradation were compared to those determined using the inhibitor in vitro method (Table 3). Rates computed using the Yb passage rate ranged from 1.5 (SSBM) to about 10-times (BM and CGM) more rapid than in vitro rates. Degradation rates computed for SSBM and ESBM using the 0.06/h rate were similar to those determined in vitro. Although slower, degradation rates computed for BM and CGM using 0.06/h were still 4 and 5-times greater than in vitro. Similar milk yields with feeding of ESBM, BM, and CGM (Table 2) suggested that these proteins provided similar amounts of RUP and that in vitro degradation rates obtained for both BM and CGM were too slow. In vivo degradation rates, based on either Yb passage rates or an assumed rate of 0.06/h, will make these proteins useful standards for development of in vitro methods.

Summary and Conclusion

In vivo ruminal degradability of SSBM, ESBM, BM, and CGM was assessed in lactating dairy cows from relative production and by measuring omasal TAAN flows in ruminally cannulated animals. Responses of DMI and yield of milk, protein, and fat with supplemental protein indicated that the basal diet supplied inadequate amounts of absorbable protein. Among supplemented diets, milk yield was greatest on ESBM and CGM, least on SSBM, and intermediate on BM. Extents of degradation for these proteins, and either passage rates observed for the small particle phase or assuming a passage rate of 0.06/h, were used to compute in vivo degradation rates. The in vivo degradation rates all were more rapid than rates determined in vitro. These four proteins will serve as standards for evaluating in vitro methods for predicting ruminal protein degradation.

TABLE 1. Composition of diets.

Item	Diet A	Diet B	Diet C	Diet D	Diet E
	(% of DM)				
Ingredients					
Corn silage	43.6	43.7	43.7	43.7	43.7
Alfalfa silage	22.2	22.2	22.2	22.2	22.2
High moisture shelled corn	30.6	21.7	20.7	25.2	23.7
Urea	2.0	2.0	2.0	2.0	2.0
Solvent soybean meal	…	8.8	…	…	…
Expeller soybean meal	…	…	9.7	…	…
Blood meal	…	…	…	5.4	…
Corn gluten meal	…	…	…	…	6.8
Sodium bicarbonate	0.5	0.5	0.5	0.5	0.5
Dicalcium phosphate	0.6	0.6	0.6	0.6	0.6
Salt	0.3	0.3	0.3	0.3	0.3
Mineral mix	0.1	0.1	0.1	0.1	0.1
Vitamin-mineral concentrate[1]	0.1	0.1	0.1	0.1	0.1
Nutrient content of diets					
CP, % of DM	15.8	19.1	19.7	20.3	19.3
NDF, % of DM	27.1	26.9	27.1	26.9	26.1
ADF, % of DM	17.5	17.3	17.3	17.0	16.7
NPN,[2] % of total N	55.3	43.9	42.0	40.0	39.0

[1]Provided (per kg of DM): Zn, 56 mg; Mn, 46 mg; Fe, 22 mg; Cu, 12 mg; I, 0.9 mg; Co, 0.4 mg; Se, 0.3 mg; vitamin A, 6440 IU; vitamin D, 2000 IU; and vitamin E, 16 IU.

[2]Proportion of total N soluble in 10% (wt/vol) trichloroacetic acid.

TABLE 2. Effect of feeding protein supplements of differing ruminal degradability on production and ruminal metabolism.[1]

Item	Diet A	Diet B	Diet C	Diet D	Diet E	SE	$P > F$[2]
Protein supplement	None	SSBM	ESBM	BM	CGM		
Production							
DMI, kg/d	21.7^{c}	23.5^{ab}	23.8^{a}	22.8^{b}	23.7^{ab}	0.6	<0.01
OM intake, kg/d	19.1	20.0	21.2	19.5	20.8	1.0	0.42
BW gain, kg/d	0.39	0.55	0.16	0.59	0.36	0.15	0.23
Milk Yield, kg/d	32.9^{c}	36.5^{b}	37.9^{a}	37.6^{ab}	38.4^{a}	1.2	<0.01
3.5% FCM	34.8^{b}	40.0^{a}	38.4^{a}	38.3^{a}	40.5^{a}	1.3	<0.01
Milk fat, %	3.77	3.87	3.57	3.64	3.73	0.11	0.09
Milk fat, kg/d	1.18^{b}	1.36^{a}	1.29^{a}	1.28^{a}	1.34^{a}	0.04	<0.01
Milk protein, %	3.04	3.12	3.07	3.08	3.15	0.05	0.09
Milk protein, kg/d	0.95^{b}	1.11^{a}	1.12^{a}	1.10^{a}	1.15^{a}	0.03	<0.01
SNF, %	8.51	8.66	8.62	8.66	8.71	0.08	0.10
SNF, kg/d	2.69^{b}	3.07^{a}	3.15^{a}	3.13^{a}	3.18^{a}	0.1	<0.01
Ruminal metabolism							
pH	6.18	6.09	6.16	6.00	6.16	0.06	0.07
Total AA, mM	3.11	3.47	2.98	3.20	2.81	0.23	0.15
Ammonia, mM	8.01^{d}	11.24^{a}	10.35^{ab}	9.94^{bc}	9.09^{cd}	0.42	<0.01
Total VFA, mM	110.2^{b}	119.2^{a}	114.9^{ab}	119.0^{a}	112.4^{b}	2.7	0.03
Acetate, mM	68.8^{b}	74.2^{a}	72.6^{a}	73.9^{a}	71.3^{ab}	1.4	0.02
Propionate, mM	22.6^{b}	24.6^{ab}	23.1^{b}	25.7^{a}	22.2^{b}	1.3	0.03
A: P ratio	3.04	3.02	3.14	2.88	3.21	0.15	0.11
Butyrate, mM	13.7	14.7	13.7	14.2	13.1	0.5	0.24
Isobutyrate, mM	1.11^{d}	1.31^{a}	1.25^{ab}	1.13^{cd}	1.21^{bc}	0.03	<0.01
Isovalerate + 2-methyl butyrate, mM	2.01	2.28	2.17	2.15	2.30	0.10	0.11
Valerate, mM	2.01	2.10	2.04	2.03	2.17	0.16	0.73
OM digestibility,[3] %	42.5	42.4	42.4	38.8	42.3	1.8	0.56
NDF digestibility,[3] %	46.9	47.9	44.8	43.6	41.5	2.9	0.50

[a,b,c]Means in rows with different superscripts differ ($P < 0.05$).

[1]BM = Blood meal; CGM = corn gluten meal; ESBM = expeller soybean meal; SE = standard error; SSBM = solvent soybean meal.

[2]Probability of a significant effect of diet.

[3]Ruminal digestibility = [(Intake – Omasal flow) / Intake] x 100.

TABLE 3. Effect of feeding protein supplements of differing ruminal degradability on intake and omasal flow of TAAN and on in vivo estimates of rate and extent of ruminal protein degradation.[1]

Item	Diet A	Diet B	Diet C	Diet D	Diet E	SE	$P > F$[2]
Protein supplement	None	SSBM	ESBM	BM	CGM		
TAAN intake, g/d							
from basal ingredients	238[a]	205[b]	212[ab]	238[a]	237[a]	12	0.04
from protein supplement		136[b]	138[b]	164[a]	133[b]	6	<0.01
Total TAAN omasal flow, g/d	329[c]	386[b]	408[ab]	440[a]	408[ab]	19	<0.01
Microbial[3]	214	240	235	224	223	16	0.66
RUP_{Total}[4]	115	146	173	216	185		
RUP_{Basal},[5] %	48.3						
$RUP_{Protein}$,[6] g/d		47.0	70.6	101.0	70.5		
Escape (Protein supplement),[7] %		34.5	51.1	61.6	53.0		
Fraction A (NPN), % total N		1.2	0.9	0.3	1.0		
Fraction B, % total N		98.7	98.9	99.5	98.4		
Fraction C (ADIN), % total N		0.2	0.2	0.2	0.7		
In vivo results							
Passage rate ($Yb\text{-}k_{SP}$),[8] /h		0.14	0.14	0.14	0.12		
Ruminal degradation rate ($Yb\text{-}k_{SP}$),[9] /h		0.26	0.13	0.09	0.11		
Ruminal deradation rate (k_p = 0.06/h),[9] /h		0.11	0.06	0.04	0.05		
In vitro results[10]							
Ruminal degradation rate, /h		0.17	0.04	0.01	0.01		
RUP,% of total CP		26	58	85	86		

[a,b,c]Means in rows with different superscripts differ ($P < 0.05$).

[1]BM = Blood meal; CGM = corn gluten meal; ESBM = expeller soybean meal; SE = standard error; SSBM = solvent soybean meal; TAAN = Total AA N.

[2]Probability of a significant effect of diet.

[3]Estimated from purines deterimined using the HPLC method of Makkar and Becker (2000).

[4]RUP_{Total} flow, g/d = Omasal flow, g/d – Microbial flow, g/d.

[5]RUP_{Basal}, % = [RUP_{Total}, g/d (diet A) / Intake, g/d (diet A)] x 100.

[6]$RUP_{Protein}$, g/d = RUP_{Total}, g/d – [Intake (basal ingredients), g/d x RUP_{Basal} (diet A)].

[7]Extent (protein), % = (TAAN flow from protein supplement / TAAN intake from protein supplement) x 100.

[8]In vivo ruminal Yb (small particle) passage rate.

[9]In vivo ruminal degradation rate = [(fraction B x kp) / (RUP – fraction C)] – kp, where kp was either the ruminal Yb passage rate or assumed to equal 0.06/h.

[10]Estimated using the inhibitor in vitro method, assuming a ruminal passage rate of 0.06/h.

Effects of Varying Dietary Protein and Energy Levels on the Production of Lactating Dairy Cows

G.A. Broderick

Introduction

There are complex relationships among dietary protein and energy composition and the amount of protein that can be utilized by the dairy cow. Dietary protein supplies absorbable protein by providing rumen-degraded protein to stimulate microbial protein formation in the rumen and by providing rumen-undegraded protein that can be digested directly by the cow. High energy diets stimulate microbial protein synthesis, thus increasing the supply of the major source of absorbable protein for the high producing cow. It is uneconomical to overfeed protein or energy. Overfeeding protein can result in excessive N excretion; nearly all of this N will be lost in the urine, the most environmentally labile form of excreted N. Overfeeding of concentrates will depress rumen pH, resulting in reduced fiber digestion and milk fat secretion as well as other metabolic problems for the cow. A feeding study was conducted using nine diets—three protein levels at each of three NDF (energy) levels—to help identify optimal amounts of dietary protein and energy.

Materials and Methods

Eighteen primiparous and 45 multiparous Holstein cows were blocked by lactation number and days in milk into seven groups of nine and randomly assigned to an incomplete Latin square trial with four periods. Diets were fed for 4-week periods before switching (total 16 weeks). The nine TMR were formulated from alfalfa and corn silages, high moisture corn, solvent soybean meal, plus minerals and vitamins (Table 1). Dietary forage was 60% from alfalfa silage and 40% from corn silage on all diets; NDF was varied by feeding forage at 75, 63 and 50% of dietary DM. Dietary CP was varied by adding soybean meal at the expense of high moisture corn. Milk yield and DMI were measured daily in the last 2 week of each period; yield of milk components was determined one day in each of the last 2 week of each period. Fecal and urine spot samples were collected from 36 cows in the last week of each period to estimate urinary N excretion using creatinine as a urine volume marker and fecal N excretion using indigestible ADF as an internal marker. Statistical analysis was done using proc GLM in SAS. The model included square, cow(square), period(square), CP and NDF level, and CP x NDF interactions; a conservative error term, cow(square), was used to assess statistical significance.

Results and Discussion

There were no significant interactions ($P \geq 0.21$) between dietary CP and NDF (energy) for any production or metabolism trait in the trial. Therefore, it was possible to make simple comparisons within the three levels of CP and NDF, without having confounding effects of CP on energy level or vice versa. Intake of DM and fat yield were influenced ($P \leq 0.03$) by CP content of the diet; both were lower on the lowest protein diet (15.1% mean CP) than on the two higher protein diets (Table 2). There were linear increases in milk urea and urinary N excretion, and linear decreases in N efficiency (milk N/N intake), with increasing dietary CP. Thus, the principal production effect of increasing dietary CP (by adding soybean meal) in cows averaging 34 kg/d of milk was to increase feed intake and milk fat yield. Effects of dietary energy content on milk production were more dramatic. There were linear increases in BW gain, milk yield, yield of protein, true protein, lactose and SNF, milk/DM intake, and milk N/N intake, and linear decrease in milk urea,with decreasing dietary NDF (Table 2). Component yield paralleled milk concentration except for fat, which declined with reduced dietary NDF; fat yield was higher at 32% dietary NDF than at 28% NDF. Yield of FCM was lower on the lowest energy diet. Increasing dietary energy (by reducing dietary forage and hence NDF) improved milk yield and efficiency and, except for milk fat, yield of milk components.

The effects of diet on N metabolism in this trial are shown in Table 3. As expected, there were linear increases in N intake and urinary N excretion with dietary CP, as well as a smaller influence of CP on fecal N excretion. Urinary N excretion nearly doubled, while fecal N increased a more modest 15%, with the increase from 15.1 to 18.4% dietary CP. As dietary energy content was increased by reducing mean NDF from 36 to 28%, urinary N declined linearly by about 12%. Interestingly, milk N secretion actually increased to a somewhat greater degree over this range of dietary energy, even though there was no significant effect of fecal N excretion. These trends were more clearly illustrated when N metabolism was expressed as a proportion of N intake: increasing CP from 15.1 to 18.4% reduced capture of milk N from 31 to 25% of dietary N; urinary N excretion was increased from 23 to 35% of dietary N, and fecal N declined from 45 to 41% of dietary N, over this range. Clearly, if milk production were not reduced, the greatest N efficiency would make the lowest protein diet the most economical—the one giving the least labile urinary N and the one that would be environmentally the most sustainable. Expressed as a proportion of N intake, there was a comparable increase in milk N secretion for each percentage unit decrease in urinary N excretion, when dietary energy content was increased. A significant effect of diet on urinary purine derivative excretion, an indicator of microbial protein formation in the rumen, also was observed. When dietary energy was increased by reducing NDF from 36 to 28%, purine derivative excretion increased by about 20%. This suggested that microbial protein supply also increased by a similar amount (Table 2).

Summary and Conclusion

Three levels of protein, each at three levels of energy, were fed to lactating cows. Increasing CP from 15.1 to 18.4% by adding soybean meal to the diet had only a small positive effect on DM intake; also, milk fat yield was higher at 16.7% CP than at 15.1% CP. However, there were large increases in milk urea and NPN and in urinary N excretion, and a substantial decrease in N efficiency, over this range of dietary protein. Increasing dietary energy by reducing forage (from 36 to 28% NDF) gave rise to linear increases in BW gain, yield of milk and milk components (except for milk fat), and milk/DM intake and milk N/N intake, as well as linear decreases in milk urea and urinary N excretion. Increasing dietary energy resulted in similar degrees of increase in milk N secretion and decrease in excretion of environmentally labile urinary N.

Table 1. Composition of diets.[1]

Diet		A	B	C	D	E	F	G	H	I
	NDF		High			Medium			Low	
Ingredient	CP	Low	Medium	High	Low	Medium	High	Low	Medium	High
						(% of DM)				
Alfalfa silage		43.8	43.8	43.8	37.3	37.3	37.3	30.8	30.8	30.8
Corn silage		30.9	30.9	30.9	25.3	25.3	25.3	19.3	19.3	19.3
Rolled high moisture shelled corn		21.5	17.1	12.6	31.4	27.0	22.5	41.7	37.3	32.8
Solvent soybean meal		1.0	5.3	9.8	2.9	7.3	11.8	4.8	9.3	13.7
Roasted soybeans		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Sodium bicarbonate		0.0	0.0	0.0	0.25	0.25	0.25	0.50	0.50	0.50
Salt		0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Mineral and vitamin premix[2]		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
<u>Chemical composition</u>										
Crude protein		15.1	16.7	18.5	15.2	16.7	18.4	15.1	16.6	18.3
NDF		36.4	35.0	35.1	31.2	31.7	32.6	28.3	27.9	27.6
ADF		24.3	23.7	23.8	21.4	21.6	22.4	19.2	18.6	19.1
Ash		7.8	8.2	8.4	7.7	8.2	8.0	7.2	7.4	7.7
NDFN, % of total N		8.9	9.4	9.7	7.7	8.8	9.1	6.9	7.1	6.9
Fat		4.5	3.9	3.9	3.7	3.7	3.4	3.6	3.3	3.2
Nonfiber carbohydrate		37.5	37.8	35.9	43.4	41.3	39.3	46.8	46.0	44.5

[1]On a DM basis, diets designated as low, medium and high CP averaged, respectively, 15.1, 16.7 and 18.4% CP, and diets designated as high, medium and low NDF averaged, respectively, 35.5, 31.8 and 27.9% NDF.

[2]Provided 56 mg of Zn, 46 mg of Mn, 22 mg of Fe, 12 mg of Cu, 0.9 mg of I, 0.4 mg of Co, 0.3 mg of Se, 6440 IU of vitamin A, 2000 IU of vitamin D, and 16 IU of vitamin E/kg of DM.

Table 2. Milk production and composition.

Trait	CP, % of DM			NDF, % of DM			SE	$P > F$[1]	
	15.1	16.7	18.4	35.5	31.7	27.9		CP	NDF
Intake and yield, kg/d									
DM intake	21.3[b]	22.1[a]	22.6[a]	21.8	22.3	21.9	0.2	< 0.01	0.36
BW gain	0.45	0.61	0.51	0.39[b]	0.44[b]	0.74[a]	0.13	0.44	0.02
Milk	33.2	34.1	34.2	31.2[c]	34.0[b]	36.2[a]	0.4	0.27	< 0.01
3.5% FCM	33.2	34.5	34.3	32.9[b]	34.9[a]	34.3[a]	0.6	0.12	0.02
Fat	1.15[b]	1.22[a]	1.21[ab]	1.19[ab]	1.24[a]	1.15[b]	0.03	0.03	< 0.01
Protein	0.99	1.02	1.02	0.91[c]	1.01[b]	1.10[a]	0.02	0.20	< 0.01
True protein	0.93	0.95	0.94	0.85[c]	0.94[b]	1.02[a]	0.01	0.52	< 0.01
Lactose	1.67	1.68	1.70	1.55[c]	1.70[b]	1.81[a]	0.03	0.79	< 0.01
SNF	2.98	3.03	3.05	2.76[c]	3.04[b]	3.25[a]	0.05	0.55	< 0.01
Milk composition, %									
Fat	3.50	3.66	3.60	3.84[a]	3.69[b]	3.22[c]	0.08	0.06	< 0.01
Protein	2.98	3.03	3.02	2.95[c]	3.01[b]	3.08[a]	0.02	0.13	< 0.01
True protein	2.80	2.82	2.79	2.74[c]	2.80[b]	2.87[a]	0.02	0.29	< 0.01
Lactose	4.97	4.96	4.96	4.92[b]	4.98[a]	4.99[a]	0.01	0.74	< 0.01
SNF	8.93	8.98	8.95	8.85[c]	8.96[b]	9.06[a]	0.02	0.20	< 0.01
Efficiency, yield/intake									
Milk/DM intake	1.56	1.55	1.51	1.44[c]	1.53[b]	1.65[a]	0.02	0.13	< 0.01
Milk N/N intake	0.304[a]	0.270[b]	0.240[c]	0.248[c]	0.270[b]	0.296[a]	0.005	< 0.01	< 0.01
Milk N fractions, mg/L									
Urea N	9.2[c]	12.4[b]	16.0[a]	13.4[a]	12.7[ab]	11.5[b]	0.2	< 0.01	< 0.01
NPN	29.2[c]	32.5[b]	36.5[a]	33.0	33.1	32.3	0.3	< 0.01	0.10

[1]Probability of a significant effect of CP or NDF concentration in the diet.

[a,b,c]The three means within the same row for either CP or NDF with a different superscript are different ($P < 0.05$).

Table 3. Nitrogen metabolism.

Trait	CP, % of DM			NDF, % of DM			SE	$P > F$[1]	
	15.1	16.8	18.4	35.5	31.7	27.9		CP	NDF
Nitrogen metabolism, g/d									
N intake	516.9[c]	591.1[b]	666.8[a]	587.1	597.1	590.5	9.8	< 0.01	0.71
Milk N	159.6	162.9	164.1	147.0[c]	161.5[b]	178.1[a]	3.3	0.45	< 0.01
Urinary N	120.3[c]	164.8[b]	230.1[a]	179.4[a]	177.8[a]	158.1[b]	8.5	< 0.01	0.01
Fecal N	237.0[b]	263.4[a]	272.5[a]	260.7	257.9	254.3	7.8	< 0.01	0.83
Nitrogen metabolism, % of N intake									
Milk N	31.1[a]	27.7[b]	24.7[c]	25.3[c]	27.7[b]	30.5[a]	0.6	< 0.01	< 0.01
Urinary N	23.2[c]	28.0[b]	34.5[a]	30.2[a]	29.1[a]	26.4[b]	1.3	< 0.01	0.01
Fecal N	45.7[a]	44.2[a]	40.8[b]	44.5	43.2	43.1	1.2	< 0.01	0.54
Urinary purine derivatives, mmol/d	378.2	402.2	399.9	353.4[b]	402.3[a]	424.6[a]	7.9	0.30	< 0.01

[1]Probability of a significant effect of CP or NDF concentration in the diet.

[a,b,c]The three means within the same row for either CP or NDF with a different superscript are different ($P < 0.05$).